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La Revue *Proceedings of the Nova Scotian Institute of Science* publie les travaux de l'Institut, des articles originaux et des notes avant trait aux sciences naturelles aux Provinces atlantiques, surtout dans les domaines de la biologie et de la géologie. Les manuscrits peuvent être en anglais ou en français, et seront soumis à l'avis d'experts avant d'être acceptés.

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Un résumé dépassant pas 200 mots doit précéder le corps du texte. Le texte lui-même doit comprendre les sections suivantes: introduction, méthodes, résultats ou observations, discussion, références bibliographiques. Dans certains cas, une synthèse de deux ou de plusieurs de ces sections peut être souhaitable.

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DISTRIBUTION AND ABUNDANCE OF MYSIDS IN THE CUMBERLAND BASIN, UPPER BAY OF FUNDY

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The distribution and abundance of two species of mysids, *Neomysis americana* and *Mysis stenolepis,* in the Cumberland Basin was studied on monthly cruises from March to October 1981 and 1982. Maximum numbers and biomass occurred in summer and early fall respectively, with lower values in March and October. *N. americana* was the dominant species, averaging up to 10 adults m^{-3}; this species produced two generations per year, the first in May-June and the second overwintering generation in September-October. *M. stenolepis* produced one generation per year in May-June. Despite high turbidity and tidal currents, adult *M. stenolepis* demonstrated limited vertical migration, with greater numbers observed in the upper 2 m at night than in daylight hours. *Spartina* detritus was present in the gut of mysids throughout the study and suspended in the water at concentrations that potentially could support the mysid populations.

L'auteur a étudié la distribution et l'abondance de deux expèces de myside *Néomysis americana* et *Mysis stenolepsis* dans le Bassin de Cumberland au cours des croisières mensuelles de mars à octobre 1981 et 1982. Les maxima en nombre et en biomasse se trouvent en été et en automne respectivement avec les niveaux plus bas trouvés en mars et en octobre. *N. americana* est l'espèce dominante moyennant jusqu'a 10 adultes m^{-3}. Cette espèce produit deux générations par an, la première en mai-juin et la deuxième génération passant l'hiver en septembre-octobre. *M. stenolepsis* produit une génération par an en mai-juin. Malgré une turbité élevée et les courants de marée, l'adulte *M. stenolepsis* manifeste une migration verticale limitée. Dans la couche supérieure d'eau (2m) on observe un plus grand nombre le jour que la nuit. Les detritus de *Spartina* ont été présent dans le boyau des mysides pendant toute la période de l'étude et ont été suspendus dans l'eau à des concentrations qui pourraient entretenir les populations de mysides observées.

Introduction

The distribution and abundance of mysids in the upper reaches of the Bay of Fundy, which are typified by high turbidity and extreme tidal ranges, are poorly understood. The existence of large numbers is suggested by the observations of Leim (1924) in the Minas Basin, Hildebrand (1981) in Shepody Bay and Uhazy (1980) in the Cumberland Basin. Possibly the best indicator of their abundance is that they are commonly found in the guts of fish, especially American shad (*Alosa sapidissima*) which migrate into the region from June to October (Leim 1924). Dadswell et *al.* (1983) noted that the turbid water in the Cumberland Basin reduces the mean swimming depth of shad to between 5.4 and 9.2 m. Although there have been no quantitative studies relating the biomass of fish to biomass of mysids consumed in the upper reaches of Fundy, these authors conclude that shad, as a filter feeding planktivore, could eat these organisms.

Many biological investigations of mysid species, particularly *Neomysis americana,* have been conducted along the east coast of North America because of their abundance and importance as food for fish and possible role as consumers of detritus (e.g. Maurer & Wigley 1982; Williams 1972; Herman 1963). It has been suggested that mysids and zooplankton in the upper Bay of Fundy derive a substantial amount of their energy from *Spartina* detritus (Gordon et *al.* 1985b). To clarify the importance of macroplankton in this turbid environment and possible links between detritus and fish, I undertook a study of the species distribution and relative abundance of mysids in the shallow depths of the Cumberland Basin during months when shad are present. This is a contribution to studies in the upper reaches of Bay of Fundy, an area which has received increased attention during the past decade in response to proposals for tidal power development (Gordon and Dadswell 1984).

Study Site

The study was conducted in the Cumberland Basin, a 118 km^2 estuary at the head of the Bay of Fundy (Fig. 1). The mean tidal range is approximately11 m and can reach 16 m on high spring tides. Strong tidal currents averaging 0.6-1.0 m sec^{-1} (Amos and Asprey 1981) create very turbid conditions; concentrations of suspended sediment vary from 0.1 to 1.0 g L^{-1} and increase with depth and towards the head of the Basin. Salinity along the estuary varies between $22\,^0/_{00}$ and $34\,^0/_{00}$ and temperature, which is often uniform from surface to bottom, has a winter minimum of -1.5°C and a

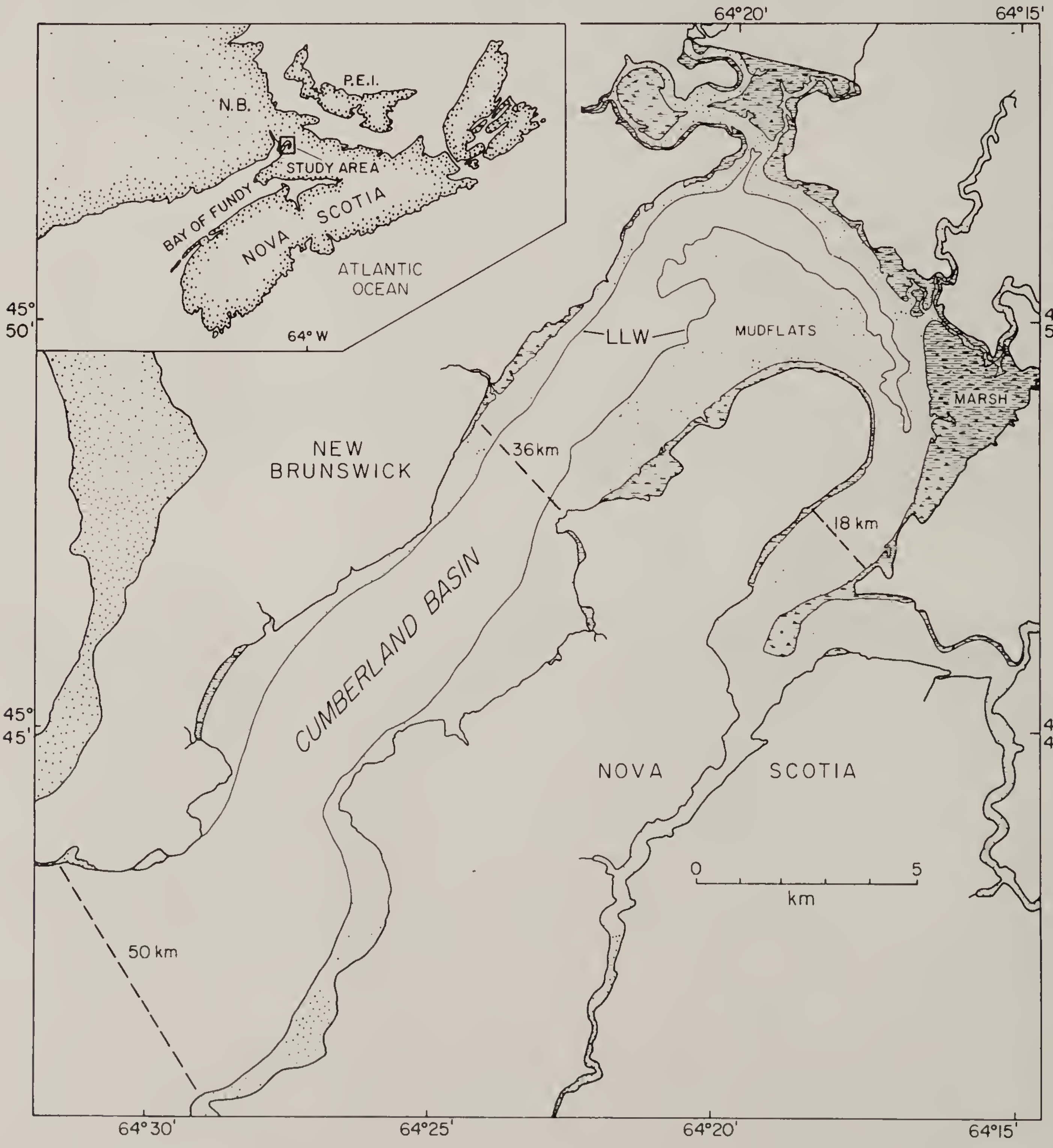

Fig 1 Map of the Cumberland Basin showing major salt marsh and mudflat areas, approximate tidal excursion limits and distance seaward from the head of salt water at mean high tide. LLW indicates lowest low water.

summer maximum of 18° C. Depth at mean sea level averages 7 and 12 m for the inner and outer Basin respectfully. The Cumberland Basin is typified by large tracts of saltmarsh dominated by *Spartina alterniflora* (Gordon *et al.* 1985a) and extensive mudflats.

Methods

Mysids were collected monthly from a local fishing boat from June to October in 1981 using a 0.5 m diameter 600 μm mesh plankton net towed at a mean depth of 6 m. Although this mesh size underestimated the number of juvenile mysids, it efficiently caught adult mysids and did not clog with the high amounts of macrodetritus in the water. The net was fitted with a General Oceanics digital flowmeter to determine the volume of water sampled. Continuous tows of 30 min. duration each were made over one complete tidal cycle throughout the Cumberland Basin. A second series of samples was collected monthly from either the RV J.L. Hart or a local fishing boat between March and September (except July) in 1982; nets similar to those used in 1981 were towed for one hour continuously over one or two complete tidal cycles at the mouth of the Basin. Most samples were collected in duplicate with one net deployed near the surface (0 - 2 m) and the other at a fixed midwater depth ranging from 2 - 19 m.

Contents of tows were preserved in 5% formalin. Results from tows taken in 1982 were used for biomass and number estimates since measured volumes of water filtered were recorded from attached flowmeters. Samples were split in the laboratory with a Motoda zooplankton splitter and the mysids separated from the macrodetritus using a density gradient method by centrifuging with LUDOX solution (Schwinghamer *et al.* 1983). Mysids were identified, sorted into stages as juvenile or adult (immature or mature) according to size and counted. Juveniles had no secondary sexual characteristics and were less than 6 mm in body length. Mysid wet weights were measured to calculate biomass per unit volume seawater. Actual numbers and biomass per m^3 of seawater were averaged for each sampling date, both for daylight and nighttime hours and the entire day.

The detritus was dried and weighed to calculate the amounts and distribution of macrodetritus for a concurrent study (Gordon *et al.* 1985b) and to test for correlations with mysid population distribution. Mysid numbers were analyzed to confirm any vertical movements through the water column. Statistical tests on the data used BMDP programs (Dixon and Brown 1979).

During the 1982 sampling, the location of the tows was standardized to the potential location the water mass would occupy at mean high water (Gordon *et al.* 1985b). Estimated current velocities are higher than the maximum swimming velocity of mysids as *Neomysis americana* (Hargreaves 1982) so they could be swept to these high tide positions.

The respiratory potential of mysids in the water column was estimated from the multiple regression of oxygen uptake by *Diaptomus* (Comita 1968). Using published data to confirm realistic values for mysids, this regression accounted for 56% of actual oxygen consumption in *Neomysis americana* (Smith and Hargreaves 1984) and *Neomysis awatschensis* and *Archaeomysis grebnitzhui* (Jawed 1973).

Results

Neomysis americana and *Mysis stenolysis* were the only mysid species collected during the study. In March of 1982 no *N. americana* were collected and only 0.02 *M. stenolepis* m^{-3} were captured at the mouth of the Basin. *N. americana*, present in all

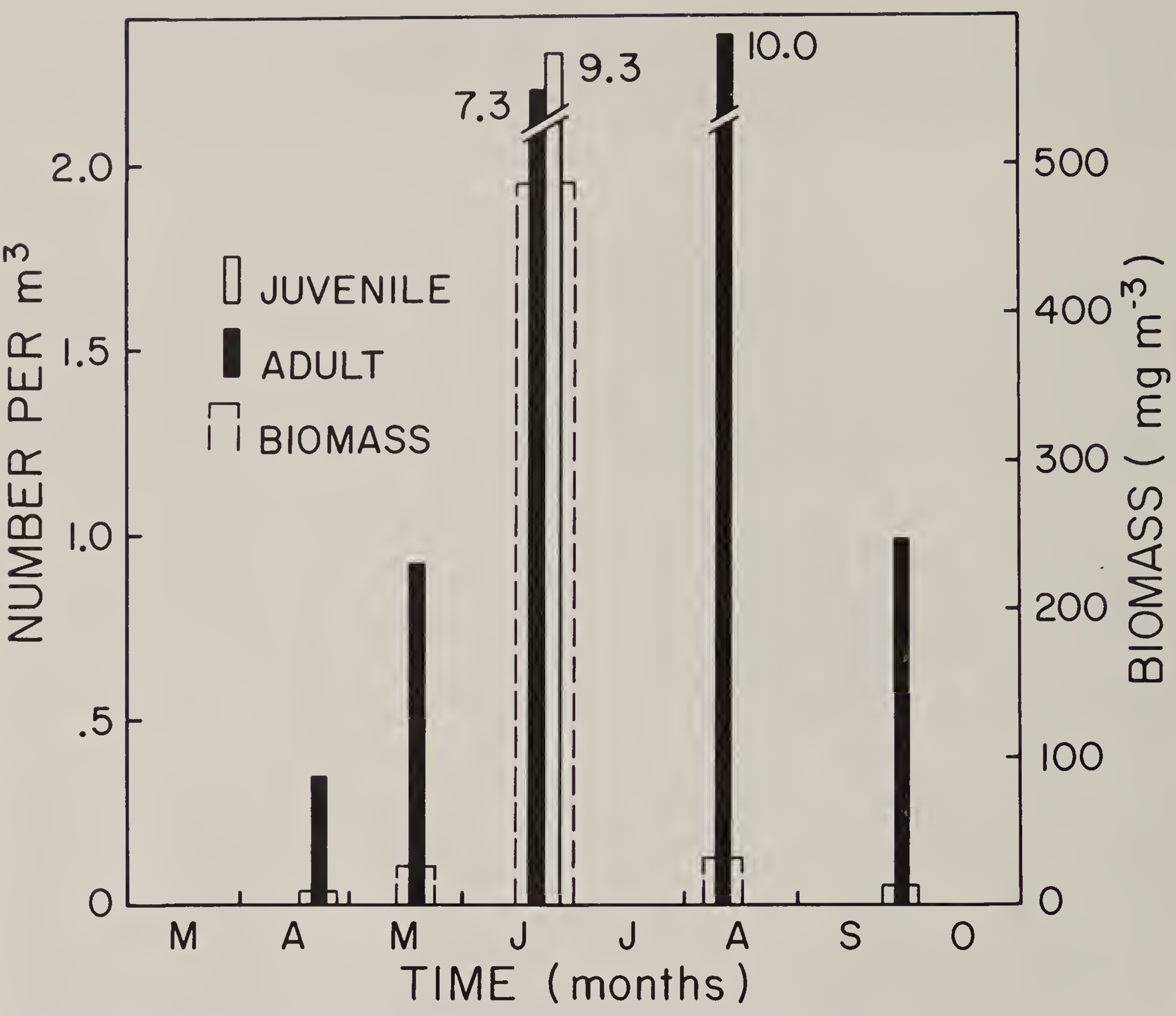

Fig 2 Average daily number and biomass per m^3 of *Neomysis americana* collected at mid-depth from the Cumberland Basin in 1982.

samples collected in successive months, was the dominant species in numbers from April to September and in biomass from June to August (Fig. 2). Large numbers of juvenile *N. americana*, averaging 73 m^{-3} at midwater depths, were caught in June. These developed into immature adults by August which gave the maximum average population density of 10.0 *N. americana* m^{-3} in 1982. Biomass followed the same general pattern with very low weights in spring which rapidly increased to the maximum biomass of 488 mg wet weight m^{-3} in June. This resulted from the presence of overwintering and gravid adults as well as many juveniles. Biomass decreased to 5.5 mg wet weight m^{-3} by September. Some of the summer generation had matured by the end of September and were ovigerous; a few juveniles representing the second generation for the year were observed at this time.

M. stenolepis was not collected in June 1982. No sampling was carried out in July. From observations during 1981, it appears that *M. stenolepis* has one generation per year. Juveniles from overwintering adults were first encountered in May. Adults, all of which were female, disappeared from the population in June and the juveniles matured to reach a maximum biomass of 35.9 mg wet weight m^{-3} in September 1982 (Fig. 3). This also corresponds to the maximum average population of *M. stenolepis* of 0.13 mysids m^{-3} during the study. Observation in 1981 indicated *M. stenolepis* had a similar pattern of abundance to that in 1982 except for a summer peak, after which the population decreased to low numbers in October.

Location of the tows at mean high water along the axis of the estuaries in 1982 was plotted against the total mysid biomass in each tow (Fig. 4). There was significant

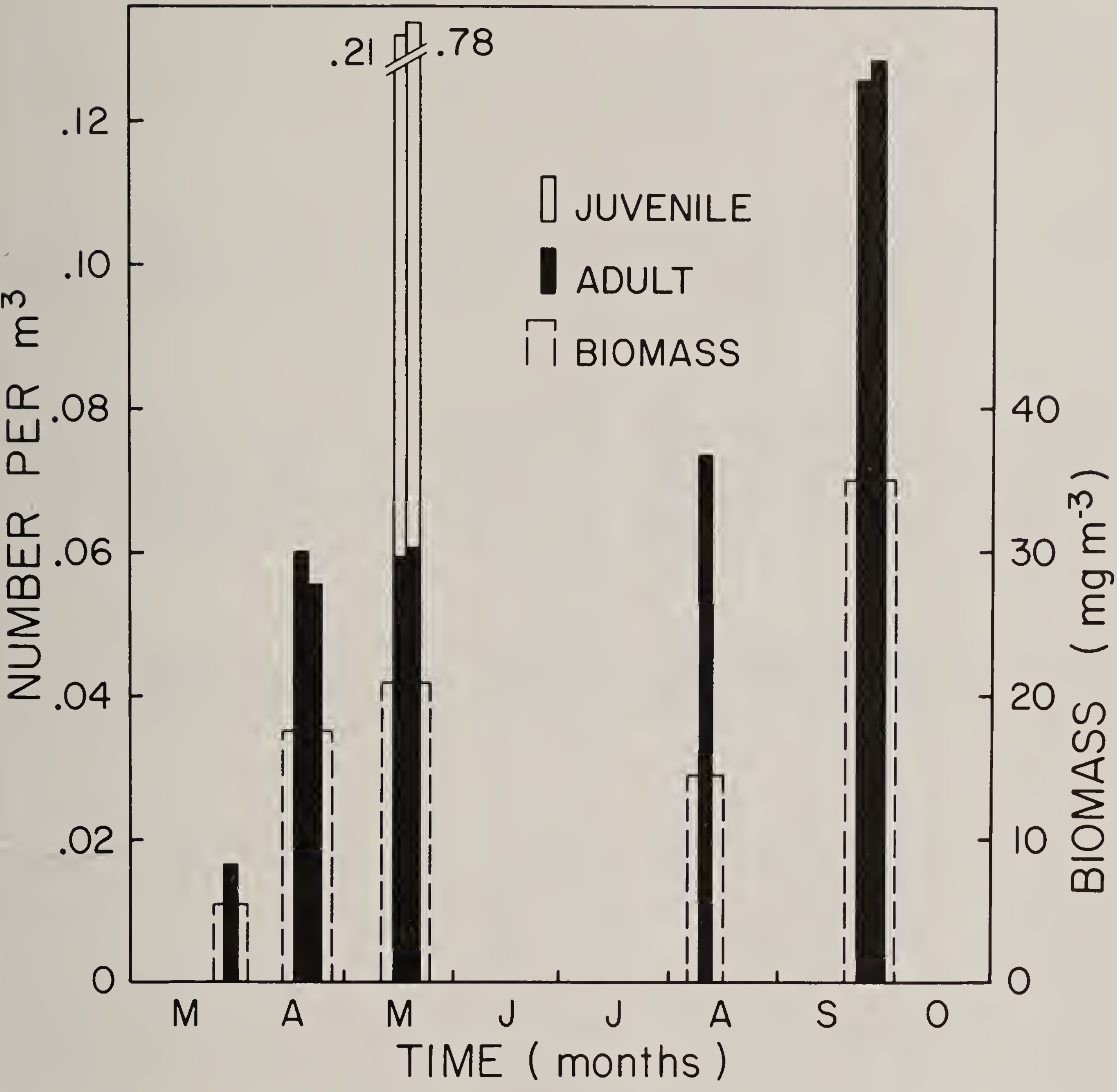

Fig 3 Average daily number and biomass per m³ of *Mysis stenolepis* collected at mid-depth from the Cumberland Basin in 1982.

positive correlation ($r^2 = 0.29$, $n = 160$, $p < 0.001$) between increasing biomass and location toward the head of Cumberland Basin. Similarly, macrodetritus greater than 600 μm, 85% of which is clearly of *Spartina* origin, and suspended sediment also increased in this direction (Gordon *et al.* 1985b; Amos and Asprey 1981). There was no significant correlation between the abundance of each species and the amount of suspended *Spartina* macrodetritus in the water.

Average number of each species per m³ collected in shallow and mid water depths during day and night (Tables I & II) were analyzed for possible diurnal movement. There were significantly more adult *M. stenolepis* in deeper water during daylight hours ($t = -3.81$, $p < 0.001$, $df = 81.9$) but there was no avoidance of surface water at night; vertical migration was probably initiated at the onset of darkness. No significant differences in the vertical distribution of adult *N. americana* nor the juveniles of each species was observed. Using a t test, there was also no significant difference in number and biomass of mysids between ebb and flood tides.

Oxygen consumption was calculated from biomass of both species per m^{-3} over the study period with correction for temperature differences in various sampling dates. The total amount of oxygen consumed was expressed as organic carbon to determine the feeding potential of mysids in the estuary and to compare this to a food

Table I Average number of adult *Neomysis americana* per m^3 collected during day and night sampling at shallow (0-2 m) and midwater (2-19 m) depths from the Cumberland Basin in 1982. N = number of tows.

	Day							
	Shallow				Midwater			
Date	Mean	Range	± SD	N	Mean	Range	± SD	N
March 30					0.00			6
April 19								
April 20					0.03	0.00-0.12	0.05	6
April 21	0.00			1	0.12	0.06-0.34	0.14	6
April 22	0.00			3	0.00			3
May 18	0.47	0.02-2.16	0.76	7	1.40	0.00-4.74	1.68	7
May 19	0.06	0.00-0.22	0.10	4	0.25	0.05-0.44	0.19	4
June 23					9.24	0.62-25.84	6.99	14
August 12					10.03	0.11-45.18	15.00	9
September 27	3.00			1	1.32			1
September 28	0.36	0.00-1.09	0.63	3	0.81	0.17-1.03	0.23	3
September 29	0.07			1	0.95			1

	Night							
	Shallow				Midwater			
Date	Mean	Range	± SD	N	Mean	Range	± SD	N
March 30								
April 19					<0.01			4
April 20					0.01	0.00-0.03	0.01	10
April 21	0.01	0.00-0.02	0.01	2	<0.01	0.00-0.01	0.01	4
April 22	0.12	0.01-0.29	0.15	3	1.79	0.01-3.97	2.01	3
May 18	0.07	0.00-0.12	0.06	3	0.48	0.00-2.14	0.75	8
May 19	1.53	0.45-2.54	0.96	6	1.49	0.07-3.59	1.37	6
June 23					9.59	8.57-10.13	0.88	3
August 12								
September 27								
September 28	1.58	0.80-2.82	0.83	6	0.88	0.20-1.87	0.70	6
September 29	1.58	0.08-2.19	0.79	3	1.76	0.71-2.55	0.89	4

Table II Average number of adult *Mysis stenolepis* per m³ x 10^{-2} collected during day and night sampling at shallow (0-2 m) and midwater (2-19 m) depths from the Cumberland Basin in 1982. N = number of tows.

	Day							
	Shallow				Midwater			
Date	Mean	Range	± SD	N	Mean	Range	± SD	N
March 30					1.56	0.65-2.50	0.71	6
April 19								
April 20					4.02	0.00-12.20	4.64	6
April 21	0.00			1	4.77	0.00-12.86	5.05	6
April 22	0.03	0.00-0.09	0.05	3	0.00			3
May 18	2.89	0.00-10.54	3.99	7	10.40	0.00-35.85	13.74	7
May 19	0.00			4	0.16	0.00-0.62	0.31	4
June 23					0.00			14
August 12					7.36	0.00-35.42	14.25	9
September 27	1.20			1	5.07			1
September 28	0.92	0.00-8.45	2.65	10	12.12	5.39-26.18	6.61	11
September 29	0.00			1	23.24			1

	Night							
	Shallow				Midwater			
Date	Mean	Range	± SD	N	Mean	Range	± SD	N
March 30								
April 19					0.06	0.00-0.23	0.12	4
April 20					4.57	0.00-26.52	8.07	10
April 21	1.28	0.1-2.46	1.67	2	6.72	0.00-15.33	7.47	4
April 22	1.75	0.00-4.05	2.08	3	7.04	0.01-12.21	6.32	3
May 18	0.15	0.00-0.44	0.25	3	2.54	0.00-10.85	4.03	8
May 19	10.54	0.00-16.67	6.66	6	10.13	0.55-25.53	8.37	6
June 23					0.00			3
August 12								
September 27								
September 28	5.85	0.00-26.67	8.09	10	12.65	2.28-32.93	9.15	10
September 29	3.60	0.39-7.86	3.49	5	11.12	5.05-18.69	5.14	5

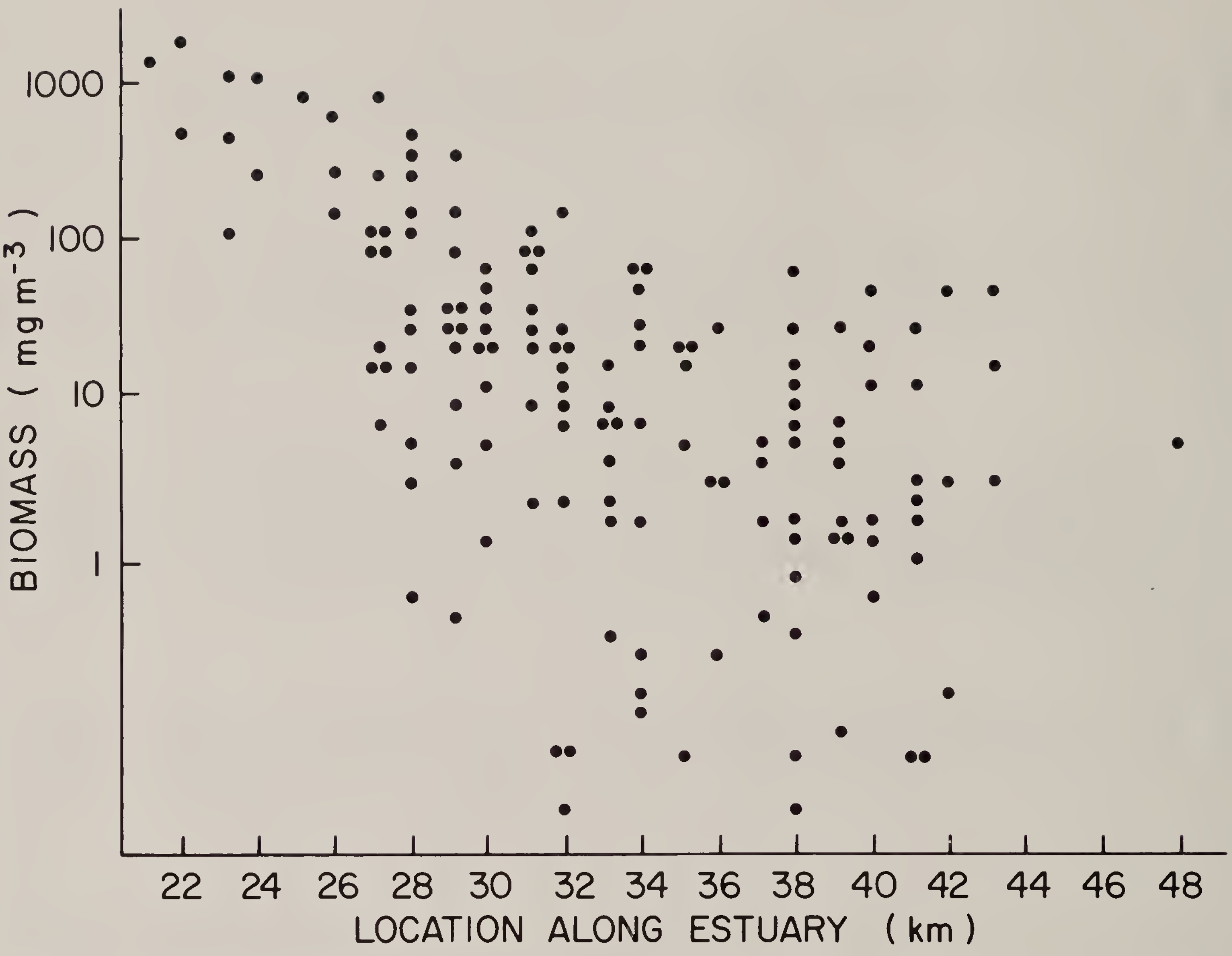

Fig 4 Biomass of mysids collected from each sample tow in the Cumberland Basin plotted against location corrected to high tide position.

supply potentially available as macrodetritus. This varied from 0.001 to 0.510 mg C m^{-3} respired per day. From a concurrent study, the mean concentration of *Spartina* detritus in the water column was 15 mg m^{-3} (Gordon et *al.* 1985b) which represents 4.5 to 6.5 mg C m^{-3} (Gordon et *al.* 1985a).

Discussion

Observations over two sampling seasons in Cumberland Basin showed that changes in mysid propulation structure and abundance were similar to other temperate areas; there are distinct seasonal fluctuations in mysid populations in all temperate regions. Hopkins (1965), amongst others, described how *N. americana* is abundant in the Delaware estuary from April to September and had a summer maximum in surface tows of 3300 m^{-3} in June and 800 m^{-3} in July. *N. americana* in the Cumberland Basin appears to have a similar pattern, increasing from low numbers in March - April to a maximum in summer as a result of breeding, then declines in numbers in September - October. *M. stenolepis,* with low numbers in spring, a population maximum in September, and possible low abundance in fall, also has these seasonal fluctuations. Life histories of *N. americana* and *M. stenolepis* in the Basin, with two and one generations per year respectively, are in agreement with those described for the same species near the mouth of the Bay of Fundy (Pezzack and Corey 1979; Amaratunga and Corey 1975).

N. americana was the dominant species of mysid, as has been observed in other areas along the east coast of North America (e.g. Hopkins 1965; Wigley and Burns

1971; Williams 1972). Although population abundance (average number per m^3) seems low in comparison to observations in other areas, *N. americana* is relatively abundant. For example, one tow in June 1982 had 25 adults and 261 juveniles m^{-3}. As stated by Hulbert (1957), a population of *N. americana* greater than 10 m^{-3} is a "relatively large concentration".

The decline in number of mysids in summer-early fall might be partly due to predation by the American shad *Alosa sapidissima*. Large numbers of shad, originating along the entire Atlantic coast of North America, migrate into the upper reaches of Fundy from June to October, peaking in July (Dadswell *et al.* 1983). This is the most important large pelagic fish to enter the Cumberland Basin and individuals concentrate at shallow depths. Leim (1924) found that *N. americana* was the major food source of mature shad in nearby Scotsman Bay. Similarly, adult shad along the Pacific coast in the Sacramento - San Joaquin Delta of California were shown to feed primarily on a slightly larger mysid, *Neomysis awatschensis* (Stevens 1966); the stomach of one shad contaïned in excess of 4000 mysids. Other pelagic fish as the alewife *Alosa pseudoharengus* and blueback herring *Alosa aestivalis* are also numerous in this area and have been observed to eat mysids (H. Stone unpublished data). In addition, *N. americana* is consumed by juvenile fish such as the American smelt *Osmerus mordax* and smooth flounder *Liopsetta putnami* in the upper Bay of Fundy (Imrie and Daborn 1981) and *M. stenolepis* is the "principal prey" of six species of fish, including white hake *Urophycis tenuis,* in Passamaquoddy Bay, lower Bay of Fundy (Tyler 1972).

The decline of mysid populations in the fall might also be due to the migration of animals to deeper water outside Cumberland Basin. Hopkins (1965) noted low numbers of *N. americana* in surface water of the Indian River Inlet, Delaware, during late fall and winter, perhaps in response to decreasing water temperature. Amaratunga and Corey (1975) observed that *M. stenolepis* in Passamaquoddy Bay moved to deeper water (20-50 m) in autumn, possibly to breed. Tows in Cumberland Basin were not deeper than 19 m nor were any made in late fall and winter so emigration cannot be verified. However, *M. stenolepis* was absent and *N. americana* in very low abundance, <1 mysid m^{-3}, in oblique tows taken at the mouth of the Cumberland Basin in February 1980 (G. Daborn unpublished data).

Movement of mysids, especially *N. americana* through the water column in response to light is well documented (eg. Hulbert 1957; Herman 1962; Hopkins 1965). Limited vertical migration in the Cumberland Basin with only adult *M. stenolepis* exhibiting significant diurnal movement could be the result of low light and strong tidal turbulence. High levels of suspended material in the Basin reduced the 1% depth of light penetration to less than 2 m (Prouse 1983) and on some occasions midday light levels at 1 m depth were below 4.25 Wm^{-2} (Prouse unpublished data from Hargrave *et al.* 1983). Mauchline (1980), reviewing mysid behavioral responses, pointed out that 10^3 to 10^4 lux (4.25 - 42.5 Wm^{-2}) inhibits mysid vertical movement towards the surface whereas 4 x 10^{-2} lux (2 x 10^{-4} Wm^{-2}) or less can initiate positive phototaxis. Thus the migratory response of mysids to light in the Basin would fluctuate greatly depending on the amount of suspended material and the incident radiation. In addition, very strong tidal turbulence could impede the swimming of mysids, especially the smaller *N. americana* and juveniles of both species, so that they are randomly mixed in the water column. *N. americana* has a routine swimming velocity of 7 cm sec^{-1} (Hargreaves 1982), whereas larger mysids such as *M. stenolepis* have a greater swimming speed and could perhaps have directed movement under highly turbulent conditions.

Mysids are omnivores, feeding on a great diversity of material (reviewed by Mauchline 1980). Diatoms can be a major food item (Siegfried and Kopache 1980; Kost and Knight 1975) and Fulton (1982a, b) recognized *N. americana* as a predator of copepods. Fulton also observed the dominance of unidentified detritus in the guts of *N. americana*. Teal (1962) has described how detritus from *Spartina alterniflora* can provide food for fauna of a Georgia saltmarsh and laboratory studies on *M. stenolepis* indicate an ability to digest cellulose (Foulds and Mann 1978; Wainright and Mann 1982). It is likely that the large amounts of salt marsh detritus in suspension originating from extensive *Spartina* marshes in the Cumberland Basin are an important energy source for mysids. Very high ingestion rates of *Spartina* detritus by *N. americana* have been observed in North Inlet, South Carolina (Zagursky and Feller 1985); when fed *Spartina* detritus in the laboratory these mysids consumed over 200% of their body carbon per day.

Preliminary observations by microscopic examination indicate that both species had *Spartina* detritus in their guts. Further, as calculated above, the carbon content of detritus suspended in the water was much greater than the daily carbon requirements for mysid respiration and could potentially support the population. It has been stated that mysids consume the most abundant food available (Raymont *et al.* 1964). As phytoplankton production is low, on the order of 15 g C m^{-2} y^{-1} (Prouse *et al.* 1984), and the copepod biomass is considerable but extremely patchy (Daborn 1984), *Spartina* detritus could be a major source of food for these organisms in the upper reaches of the Bay of Fundy.

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References

Amaratunga, T. and **Corey, S.** 1975. Life history of *Mysis stenolepis* Smith (Crustacea, Mysidacea). *Can. J. Zool.* 53: 942-952.

Amos, C.L. and **Asprey, K.W.** 1981. An interpretation of oceanographic and sediment data from the upper Bay of Fundy. Bedford Institute of Oceanography Report Series BI-R-81-15, 143 p.

Comita, G.W. 1968. Oxygen consumption in *Diaptomus. Limnol. Oceanogr.* 13: 51-57

Daborn, G.R. 1984. Zooplankton studies in the upper Bay of Fundy since 1976. *Can. Tech. Rep. Fish. Aquat. Sci.* No. 1256: 135-162.

Dadswell, M.J., Melvin, G.D. and **Williams, P.J.** 1983. Effect of turbidity on the temporal and spatial utilization of the inner Bay of Fundy by American shad (*Alosa sapidissima*) (Pisces: Clupeidae) and its relationship to local fisheries. *Can. J. Fish. Aquat. Sci.*, 40 (Suppl. 1): 322-330.

Dixon, W.J. and **Brown, M.B.** [ed.], 1979. Biomedical computer programs P-series. University of California Press, Berkeley. 880 p.

Foulds, J.B. and **Mann, K.H.** 1978. Cellulose digestion in *Mysis stenolepis* and its ecological implications. *Limnol. Oceanogr.* 23: 760-766.

Fulton, R.S. III 1982a. Preliminary results of an experimental study of the effects of mysid predation on estuarine zooplankton community structure. *Hydrobiologia* 83: 79-84.

Fulton, R.S. III 1982b. Predatory feeding for two marine mysids. *Mar. Biol.* 72: 183-191.

Gordon, D.C. Jr., and **Dadswell, M.J.** 1984. Update on the marine environmental consequences of tidal power development in the upper reaches of the Bay of Fundy. *Can. Tech. Rep. Fish. Aquat. Sci. No.* 1256: vii + 686 p.

Gordon, D.C. Jr., Cranford, P.J. and **Desplanque, C.** 1985a. Observations on the ecological importance of salt marshes in the Cumberland Basin, a macrotidal estuary in the Bay of Fundy. *Estuarine, Coastal and Shelf Sci.*, 20: 205-227.

Gordon, D.C. Jr., Prouse, N.J. and **Cranford, P.J.** 1985b. Occurrence of *Spartina* macrodetritus in the Bay of Fundy waters. *Estuaries* 8: 290-295.

Hargrave, B.T., Prouse, N.J., Phillips, G.A. and **Neame, P.A.** 1983. Primary production and respiration in pelagic and benthic communities at two intertidal sites in the upper Bay of Fundy. *Can J. Fish. Aquat. Sci.*, Vol. 40 (Suppl. 1): 229-243.

Hargreaves, B.R. 1982. Energetics of crustacean swimming. In Locomotion and Energetics in Anthropods. C.F. Herreid II and C.R. Fournier, eds. Planum Publishing Corp.: 453-490.

Herman, S.S. 1963. Vertical migration of the opossum shrimp, *Neomysis americana* Smith. *Limnol. Oceanogr.* 8: 228-238.

Hildebrand, L.P. 1981. Preliminary observations on the distribution, composition and abundance of zooplankton in Chignecto Bay during June and August 1978, with emphasis on the relationship to tidal cycles. *Can. Tech. Rep. Fish. Aquat. Sci.* No. 1036.

Hopkins, T.L. 1965. Mysid shrimp abundance in surface waters of Indian River Inlet, Delaware. Chesapeake Sci. 6: 86-91.

Hulbert, E.M. 1957. The distribution of *Neomysis americana* in the estuary of the Delaware River. *Limnol. Oceanogr.* 2: 1-11.

Imrie, D.M.G., and **Daborn, G.R.** 1981. Food of some immature fish of Minas Basin, Bay of Fundy. Proc. N.S. Inst. Sci., 31: 149-153.

Jawed, M. 1973. Effects of environmental factors and body size on rates of oxygen consumption in *Archaemysis grebritzkui* and *Neomysis awatschensis* (Crustacea: Mysidae). *Mar. Biol.*, 21: 173-179.

Kost, A.L.B. and **Knight, A.W.** 1975. The food of *Neomysis mercedis* Holmes in the Sacramento - San Joaquin Estuary. *Calif. Fish. Game*, 61: 35-46.

Leim, A.H. 1924. The life history of the shad [*Alosa sapidissima* (Wilson)] with special reference to the factors limiting its abundance. *Contr. Can. Biol.* 2: 153-284.

Mauchline, J. 1980. The biology of mysids and euphausids, 1. The Biology of Mysids, pp. 3-369, in Advances in Marine Biology, Vol. 18, J.H.S. Blaxter, F.S. Russell, M. Yonge, Eds. Academic Press, N.Y.

Maurer, D. and **Wigley, R.L.** 1982. Distribution and ecology of mysids in Cape Cod Bay, Massachusetts. *Biol. Bull.* 163: 477-491.

Pezzack, D.S., and **Corey, S.** 1979. The life history and distribution of *Neomysis amerciana* (Smith) (Crustacea, Mysidacea) in Passamaquoddy Bay. *Can. J. Zool.* 57: 785-793.

Prouse, N.J. 1983. Primary production measurements in the Bay of Fundy from March 1979 to November 1980. *Can. Tech. Rep. Fish. Aquat. Sci.* No. 1167.

Prouse, N.J., Gordon, D.C. Jr., Hargrave, B.T., Bird, C.J., McLachlan, J., Lakshminarayana, J.S.S., Sita Devi, J. and **Thomas, M.L.H.** 1984. Primary production: organic matter supply to ecosystems in the Bay of Fundy. *Can. Tech. Rep. Fish. Aquat. Sci.*, No. 1256: 65-104.

Raymont, J.E.C., Austin, J. and **Linford, E.** 1964. Biochemical studies on marine zooplankton. I. The biochemical composition of *Neomysis integer*. *J. Cons. Perm. Intern. Explor. Mer.*, 28: 354-363.

Schwinghamer, P., Tan, F.C. and **Gordon, D.C. Jr.** 1983. Stable carbon isotope studies on the Pecks Cove mudflat ecosystem in the Cumberland Basin, Bay of Fundy. *Can. J. Fish. Aquat. Sci.*, 40 (Suppl. 1): 262-272.

Siegfried, C.A. and **Kopache, M.E.** 1980. Feeding of *Neomysis mercedis* (Holmes). *Biol. Bull.*, 159: 193-205.

Smith, R.L., and **Hargreaves, B.R.** 1984. Oxygen consumption in *Neomysis americana* (Crustacea: Mysidacea), and the effects of naphthalene exposure. *Mar. Biol.*, 79: 109-116.

Stevens, D.E. 1966. Distribution and food habits of the American shad, *Alosa sapidissima*, in the Sacramento - San Joaquin Delta. Calif. Dept. Fish Game Fish. Bull., 136: 68-96.

Teal, J.M. 1962. Energy flow in the salt marsh ecosystem of Georgia. *Ecology*, 43: 614-624.

Tyler, A.V. 1972. Food resource division among northern, marine, demersal fishes. *J. Fish. Res. Board Can.* 29: 997-1003.

Uhazy, L.S. 1980. To determine the feasibility of using parasites as biological tags for determining the utilization of upper Bay of Fundy by commercially important fishes. Fundy Isles Marine Enterprises Ltd. DSS Contract 075C: FP706-8-0252, 53 p.

Wainwright, P.F., and **Mann, K.H.** 1982. Effects of antimicrobial substances on the ability of the mysid shrimp *Mysis stenolepis* to digest cellulose. *Mar. Ecol. Prog. Ser.* 7: 309-313.

Wigley, R.L., and **Burns, B.R.** 1971. Distribution and biology of mysids (Crustacea, Mysidacea) from the Atlantic coast of the United States in the N.M.F.S. Woods Hole Collection. *Fish. Bull.* 69: 717-746.

Williams, A.B. 1972. A ten year study of meroplankton in North Carolina estuaries: mysid shrimps. *Chesapeake Sci.* 13: 254-262.

Zagursky, G. and **Feller, R.J.** 1985. Macrophyte detritus in the winter diet of the estuarine mysid, *Neomysis americana*. *Estuaries* 8(4): 355-363.

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LAKE CLASSIFICATION IN NOVA SCOTIA FROM PHOSPHORUS LOADING, TRANSPARENCY AND HYPOLIMNETIC OXYGEN CONSUMPTION

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Three indices of eutrophication are used to compare effects of urbanization on seven headwater lakes near Halifax, Nova Scotia. Annual (1983) inputs of phosphorus were calculated and compared with lake Secchi transparencies and rates of consumption of hypolimnetic oxygen (Thienemann index). Results from transparency and oxygen deficits were similar but implied greater eutrophication than did the phosphorus index. Brief discussion of some inherent problems of each index is included.

Les auteurs emploient trois indices d'eutophication pour comparer les effets d'urbanization sur sept lacs sources de rivière près d'Halifax, Nouvelle Ecosse. Les apports annuels (1983) de phosphore sont calculés et comparés avec la limpidité "Secchi" des lacs et avec les taux de consommation d'oxygène hypolimnétique (indice de Thienemann). Les resultats des études de limpidité et de déficit en oxygène sont comparables mais indiquent une plus grande eutrophication que l'indice de phosphore. Les auteurs discutent les problèmes associés avec chaque indice.

Introduction

It has been predicted that land from Halifax to Subenacadie will be subjected to intense development pressures before the turn of the century (Anonymous 1981). Consequently, in 1975 a Federal-Provincial water quality agreement was signed to initiate studies of the watershed of the Shubenacadie River. Several of the 30 resultant reports discussed headwater lakes, and listed a variety of concerns ranging from sensitivity to nutrient enrichment (Hart et al. 1978), to accumulations of metals in sediments (Mudroch and Sandilands 1978).

In 1983 several of the headwater lakes were re-evaluated for their sensitivity to watershed disturbances. While the particular concerns focussed on arsenic and mercury in lake sediments, it was recognized that biogeochemical cycles of these metals are intricately linked to oxidation - reduction phenomena which, in turn, are very much a function of biological productivity in lakes. Thus, the present study was conducted in order to assess the current trophic status of seven lakes. The methods of assessment incorporated phosphorus and transparency concepts that were developed by Vollenweider and Kerekes (1980) and rates of consumption of dissolved oxygen, according to Chapra and Dobson (1981).

Methods

Water was sampled in lakes Powder Mill, Third, Three Mile, Perry, Thomas, Fletcher and Muddy Pond and in the connecting streams (Fig. 1) four times during the study period between April and December of 1983. Samples were collected at the deepest point of each lake, except for Perry Lake, where only shore sampling was possible. A two-litre Van Dorn sampler was used to collect samples from 1 m below surface, mid-depths of the water columns and from 1.5 m above the bottoms. Additional mid-column water samples were taken during the months when the lakes were thermally stratified.

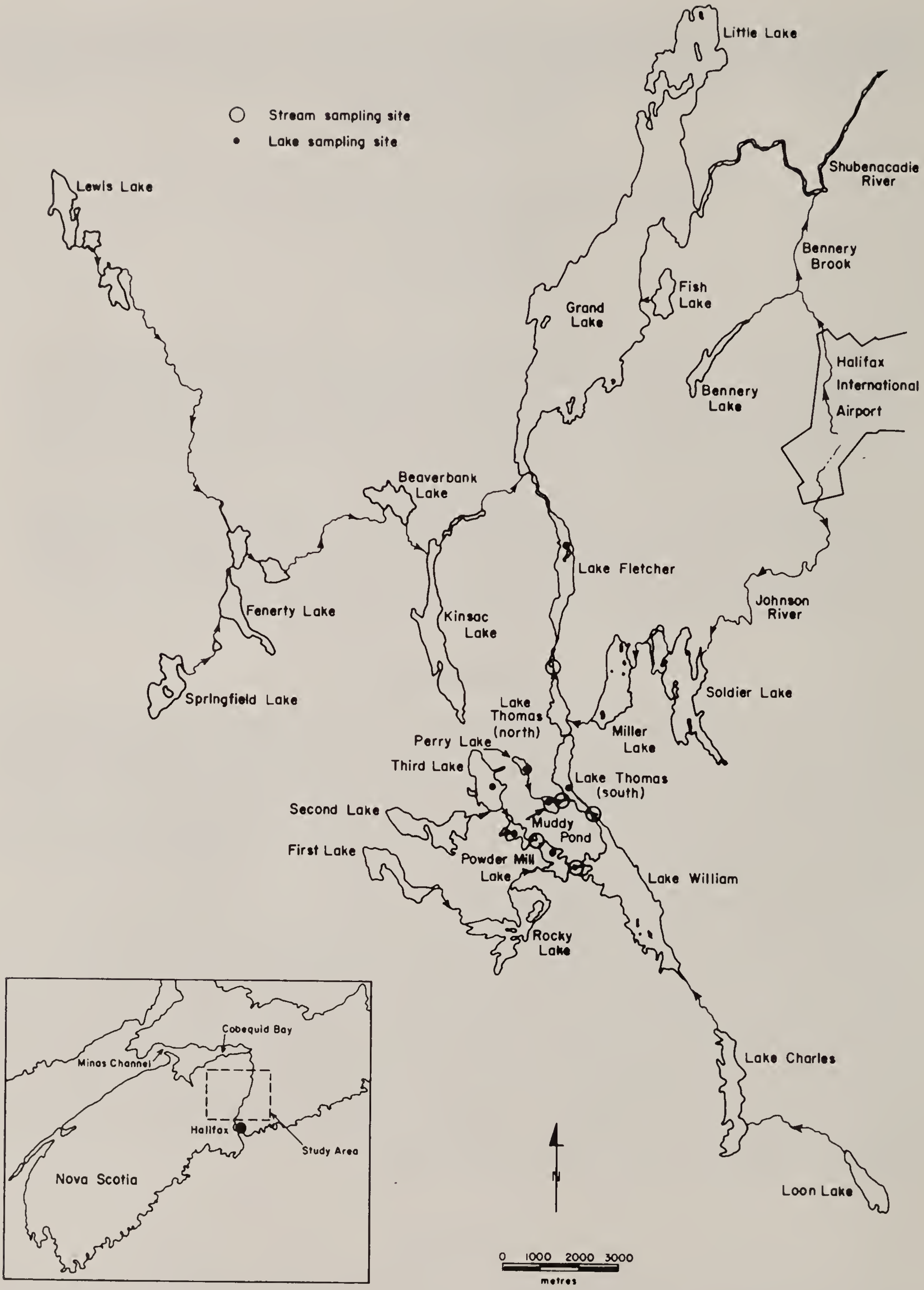

Fig 1 Headwater lakes of the Shubenacadie River.

Dissolved oxygen and temperature was measured in the field on a YSI oxygen meter (model no. 57). A 20 cm Secchi disc with alternating black and white quadrants was used to measure transparency. Phosphorus and nitrogen were analyzed in water samples by the Water Quality Branch, Inland Waters Directorate, in Moncton, N.B.

Morphometric data on most study lakes were acquired from the Shubenacadie Headwaters Environmental Survey (Table 14 in IWD 1974). Morphometric data for Three Mile Lake were obtained from Ogden (1972). The morphometry of Muddy Pond was calculated from bathymetric soundings conducted by Nova Scotia Department of the Environment (NSDOE). Flushing rates for the study lakes were obtained from Ogden (1972) and Johnson (1978). The flushing rate for Muddy Pond was calculated using a runoff coefficient of 0.64 found in the Hydrological Atlas of Canada (CNC/IHD 1978). Watershed areas of Muddy Pond and Perry Lake were calculated from a 1:10,000 orthophoto, with the assumption that the roads within the drainage area contained culverts that would not impede natural drainage. Stream flow measurements were obtained from Water Resources Branch (1984).

Trophic classifications were derived from probability curves for phosphorus and Secchi readings (Vollenweider and Kerekes 1980) and from hypolimnetic oxygen deficits, using the Thienemann trophic scale (1981).

Mean phosphorus concentrations in the lakes were calculated by adjusing for water volumes in each depth. In addition to whole-lake mean values for phosphorus, theoretical input from watershed soils were estimated by rearranging Fig. 6.11 of Vollenweider and Kerekes (1980) as follows:

$$\overline{[P]}_i = \frac{\overline{[P]}_\lambda^{\,1.22}}{1.55} \cdot (1 + \sqrt{Tw}) \qquad (1)$$

Symbols for watershed parameters discussed in the paper follow Vollenweider and Dillon (1974), where possible, such that:

- Ad is the area of the watershed to the outlet of a lake, exclusive of that lake, measured in m^2.
- Ad_i is the area of the immediate watershed surrounding a lake in m^2.
- Ad_c is the total or cumulative drainage area of a lake, measured in m^2. This includes watersheds and lakes upstream of the lake of immediate interest, but excludes the surface area of the study lake.
- q_s is the areal water loading to a lake, measured in $m^3.yr^{-1}$.
- Tw is the residence time of water in years.
- **$\overline{[P]}_\lambda$ is the mean annual phosphorus concentration in the lake, measured in $mg.m^{-3}$.**
- P_λ is the total amount of phosphorus in the lake, measured in mg.
- $\overline{[P]}_i$ is the mean phosphorus concentration of inlet waters ($mg.m^{-3}$) according to equation 1.
- P_i is the total annual input of phosphorus ($mg.yr^{-1}$) from the watershed according to concentration ($[P]_i$) and volumes of inlet streams.
- L(P) is the annual loading of total phosphorus per unit lake surface area ($mg.m^{-2}.yr^{-1}$).
- Es_i is the phosphorus export coefficient from soils in the immediate watershed area, measured in $mg.m^{-2}.yr^{-1}$ of watershed.
- Es_c is the phosphorus export coefficient from soils in the cumulative watershed area ($mg.m^{-2.yr-1}$).

Results

Phosphorus and Nitrogen Ratios and Classification of Lake Trophic Status

Mean annual total phosphorus $[\bar{P}]$ and total nitrogen $[\bar{N}]$ concentrations are presented in Table I. Third Lake was found to contain the lowest [P] with 3.5 mg.m^{-3}. Concentrations ranged up to 18 mg.m^{-3} while the mean value was 7.6 mg.m^{-3}. Lakes from several areas of the world (OECD lakes) ranged from 3.0 to 750 mg.m^{-3} (mean value of 47.1), while other Nova Scotian lakes are reported to range from 2 to 20 mg.m^{-3} with a mean value of about 8 mg.m^{-3} (Vollenweider and Kerekes 1980; Kerekes 1983).

Total nitrogen concentrations (Table I) varied from 100 to 190 mg.m^{-3} (mean value, 140 mg.m^{-3}) and were less than those reported for OECD lakes (263 to 6095, mean value, 1244 mg.m^{-3}; Vollenweider and Kerekes 1980).

Table I Mean annual concentration of phosphorus and nitrogen and corresponding trophic classifications.

Lake	Mean annual Total P mg.m^{-3}	Mean annual Total N mg.m^{-3}	$\frac{TN}{TP}$	Classification
Third	3.5	140.0	40	Ultra-Oligotrophic
Three Mile	7.0	120.0	17	Oligotrophic
Powder Mill	6.5	120.0	18	Oligotrophic
Perry	4.5	150.0	33	Oligotrophic
Muddy Pond	18.0	190.0	11	Mesotrophic
Thomas	8.0	160.0	20	Oligotrophic
Fletcher	6.0	100.0	16	Oligotrophic

Ratios of [N] : [P] were calculated to investigate if phosphorus was the probable limiting nutrient. Fricker (1981) reported that P is the limiting nutrient when the ratio is greater than 17. Table I indicates that N/P was slightly less than 17 in Muddy Pond and lakes Three Mile and Fletcher. This ratio implies that nitrogen could stimulate production in these lakes. However, more data are required to verify this speculation since concentration of N and P are low relative to the working range of the OECD lakes.

Phosphorus concentrations were compared with probablity curves of Vollenweider and Kerekes (1980) in order to classify the study lakes. Table I indicates that while most of the lakes are oligotrophic, Third Lake would appear to be ultra-oligotrophic, and Muddy Pond is mesotrophic.

Table II Estimation of phosphorus export from watersheds of study lakes.

Lake	Ad_i m^2 x 10^6	Ad_c m^2 x 10^6	q_s m^3 x 10^6	Vol m^3 x 10^6	T(w) year	$[\bar{P}]_\lambda$ mg.m^{-3}
Third	2.89	9.81	31.1	5.53	0.75	3.5
Three Mile	0.78	11.50	3.9	0.324	0.083	7.0
Powder Mill	2.93	26.22	48.4	1.84	0.038	6.5
Muddy Pond	0.29	1.26	1.3	0.032	0.025	18.0
Thomas	7.04	126.79	109.3	4.59	0.042	8.0
Fletcher	14.33	142.25	135.4	3.79	0.028	6.0

Hart (1979) undertook an environmental assessment of the surface waters of five lakes (all included in this study), in the vicinity of a proposed Industrial Park near Third Lake. His study provided some contemporary baseline data, as well as possible effects which the proposed development could have on the surface waters in the area. Sampling was carried out in the Spring, a time when phosphorus concentrations have been linked to the rate of algal growth during the following summer (Vollenweider and Kerekes 1980). Phosphorus concentration in three of the five lakes Hart studied were similar to those found in this study. Hart concluded that surface waters in the area were of high quality.

If sewage systems contributed significantly to the nutrient budget of a lake, a relationship between phosphorus and nitrogen would be expected (Vallentyne 1974). Table I shows that a greater variation exists for mean annual phosphorus concentrations between lakes than for nitrogen. Thus it is concluded that there is little evidence of phosphorus input through sewage systems.

Whole Lake Phosphorus Concentrations and Estimates of Phosphorus Loadings from Watersheds

In order to determine the input of total phosphorus from the various watersheds, a phosphorus budget was developed based on the mean phosphorus concentrations of inlet waters, calculated according to equation 1. It is necessary to consider phosphorus concentrations of inlet waters in addition to the total lake phosphorus concentrations, as use of inlet values allows for accommodation of phosphorus that is lost through sedimentation, macrophyte assimilation, and flow through the lakes. Table II shows the calculated export coefficients of phosphorus from both the immediate and cumulative watersheds of the study lakes. The export coefficients Es_i and Es_c are calculated by dividing the total input of phosphorus (P_i) from the watershed, by the areas of the immediate (Ad_i) and cumulative (Ad_c) watersheds respectively. The export coefficients are calculated from column 1, 2, and 9 in Table II.

The phosphorus export coefficient (Es_i), calculated for the immediate watershed area of the lakes ranged from 40.5 $\text{mg.m}^{-2}.\text{yr}^{-1}$ for Three Mile Lake watershed to 138.2 $\text{mg.m}^{-2}.\text{yr}^{-1}$ for Lake Thomas watershed. The arithmetic mean phosphorus export coefficient was found to be 84.5 $\text{mg.m}^{-2}.\text{yr}^{-1}$. Lakes Thomas, Powder Mill, and Muddy Pond show export coefficients greater than the calculated mean.

Estimates for the phosphorus export coefficient (Es_c), based on the cumulative watershed areas of study lakes, ranged from 2.8 $\text{mg.m}^{-2}.\text{yr}^{-1}$ for Three Mile Lake to 23.7 $\text{mg.m}^{-2}.\text{yr}^{-1}$ for Muddy Pond; the mean being 10.7 $\text{mg.m}^{-2}.\text{yr}^{-1}$. Muddy Pond, Third and Powder Mill lakes all showed phosphorus export coefficients greater than the mean. Three Mile Lake exports the least amount of total phosphorus per unit area of both immediate and cumulative watersheds.

Abbreviations explained in Methods.

			— per annum —		
P_λ mg x 10^6	$\overline{[P]}_i$ mg.m^{-3}	P_i mg x 10^6	L[P] mg.m^{-2}	Es_i mg.m^{-2}	Es_c mg.m^{-2}
27.1	3.8	155.5	187.4	53.8	15.9
2.9	8.1	31.6	195.2	40.5	2.8
14.4	6.9	334.0	786.0	113.9	12.7
0.67	23.0	29.9	598.3	103.1	23.7
44.1	8.9	972.8	858.5	138.2	7.7
26.5	6.1	825.9	784.9	57.6	5.8

Total phosphorus loadings (L(P)) were also calculated in order to compare them with the minimum, maximum and geometric mean values listed in the OECD report (Vollenweider and Kerekes 1980). Annual loadings (P_i in Table II divided by lake surface areas) ranged from 187 mg.m^{-2}.yr^{-1} for Third Lake to 858 mg.m^{-2}.yr^{-1} for Lake Thomas, with a geometrical mean of 475 mg.m^{-2}.yr^{-1} for all study lakes. The minimum OECD L(P) value was 17 mg.m^{-2}.yr^{-1}, with a geometrical mean of 1200 mg.m^{-2}.yr^{-1}. Kerekes (1983), using the OECD phosphorus relationships, found a L(P) value of 133 mg.m^{-2}.yr^{-1} for Freshwater Lake in Cape Breton.

Estimates of Phosphorus Load to Lakes from Streams

Table II lists whole-lake phosphorus concentrations which are used with equation 1 to estimate inlet concentrations and export coefficients. However, five streams interconnecting the study lakes were sampled during the study period, and daily discharge readings were taken at four of them. These measurements have provided an opportunity to compare the total phosphorus loading from the cumulative watershed areas calculated from estimates of inlet concentrations (last column in Table II) to that of the whole lake phosphorus measurements (last column in Table III).

Based on the mean total phosphorus concentrations and average discharges measured for the inlet streams (column 1 and 2 respectively in Table III), the annual total phosphorus loading to three downstream lakes was calculated. This calculation was performed by multiplying the average total phosphorus concentration measured in the streams by the average discharge rate. The result was an estimate of the amount of phosphorus loading via the streams, measured in mg per second (column 3, Table III), which was used to calculate the total annual phosphorus loading in mg.m^{-2}.yr^{-1} of lake area (column 4 of Table III). In order to calculate the total phosphorus input from the immediate upstream watershed area the immediate upstream watershed area including the lake was divided by the total annual loading from the streams (column 5, Table III). The calculation can be carried further to ascertain the total phosphorus loading per unit of cumulative upstream watershed area (column 6, Table III). The lowest annual total phosphorus loading, calculated per unit immediate watershed area (Es_i), was from Lake William watershed to Lake Thomas, (15 mg.m^{-2}.yr^{-1}). The

Table III Estimation of phosphorus export via measured concentrations in inlet waters.

Stream	Mean TP conc. mg.m^{-3}	Average discharge m^3.s^{-1}	Transp. TP; mg.s^{-1}	Annual TP loading mg.m^{-2}.yr^{-1} on lake from stream measurements
Power Mill to William	8.75	0.740	6.47	64.8 on William (204.1 x 10^6mg)
William to Thomas	7.4	1.99	14.70	409.8 on Thomas (464.4 x 10^6mg)
Muddy Pond to Thomas	15.4	0.052	0.80	22.2 on Thomas (25.1 x 10^6mg)
Thomas to Fletcher	5.2	3.76	21.1	631.1 on Fletcher (664.0 x 10^6mg)

highest was 94 $mg.m^{-2}.yr^{-1}$ calculated for phosphorus loading from Lake Thomas watershed to Lake Fletcher. The mean phosphorus contribution from the immediate watersheds of the four upstream lakes was 66 $mg.m^{-2}.yr^{-1}$. The total phosphorus loading, calculated per unit cumulative watershed (Es_c) ranged from 5.2 $mg.m^{-2}.yr^{-1}$, contributed by the total drainage area of Lake Thomas, to 19.2 $mg.m^{-2}.yr^{-1}$ contributed by the total drainage area of Muddy Pond. The mean contribution from cumulative watersheds was 9.6 $mg.m^{-2}.yr^{-1}$.

Comparisons of the export coefficients per cumulative watershed area calculated using whole lake phosphorus concentrations and stream concentration are listed as follows. The export coefficient of phosphorus (Es_c) calculated for the Lake Thomas watershed using whole-lake concentrations was 5.8 $mg.m^{-2}.yr^{-1}$ and 5.2 $mg.m^{-2}.yr^{-1}$ using stream concentrations. For the Muddy Pond watershed, the Es_c calculated from whole-lake concentrations was 23.7 $mg.m^{-2}.yr^{-1}$ and 19.2 $mg.m^{-2}.yr^{-1}$ based on stream concentrations. Lake William watershed had Es_c of 7.7 $mg.m^{-2}.yr^{-1}$ calculated from whole-lake concentrations and 6.1 $mg.m^{-2}.yr^{-1}$ based on stream concentrations. In the case of Powder Mill Lake watershed the Es_c calculated from whole-lake concentrations was 12.7 $mg.m^{-2}.yr^{-1}$ and 7.7 $mg.m^{-2}.yr^{-1}$ based on stream concentrations.

Different figures calculated for Es_c using whole-lake concentrations as opposed to stream concentrations, result from the fact that because of fluctuating stream flows, they are more instantaneous and therefore variable indicators of watershed conditions. Lakes, however, might be considered as integrators of fluctuations over time because their larger volumes tend to dampen fluctuations in inlet waters. Despite modest differences between measured inputs of phosphorus via streams and estimates produced from whole-lake concentrations according to Vollenweider and Kerekes (1980) we conclude that equation (1) is applicable to the watersheds we examined.

Oxygen Content of Lakes

Oxygen concentrations were influenced by stratification in all study lakes. This is evident from the isopleths for oxygen saturation (Figures 2 to 7). Third Lake, Three Mile Lake and Muddy Pond, showed hypolimnetic oxygen deficits of up to 70% less

TP discharge per unit immediate watershed area (including lake) Es_i; $mg.m^{-2}.yr^{-1}$	TP discharge per unit cumulative watershed area Es_c; $mg.m^{-2}.yr^{-1}$
P.M. W'shed to Wm. 69.66 from P.M. W'shed (2.93 km^2)	7.7 P.M. W'shed + (26.6 km^2)
Wm. W'shed to Th. 15.00 from Wm. W'shed (30.95 km^2)	6.1 Wm. W'shed + (76 km^2)
M.P. W'shed to Th. 86.55 from M.P. W'shed (.29 km^2)	19.2 M.P. W'shed + (2.3 km^2)
Th. W'shed to Fl. 94.32 from Th. W'shed (7.04 km^2)	5.2 Th. W'shed + (128 km^2)

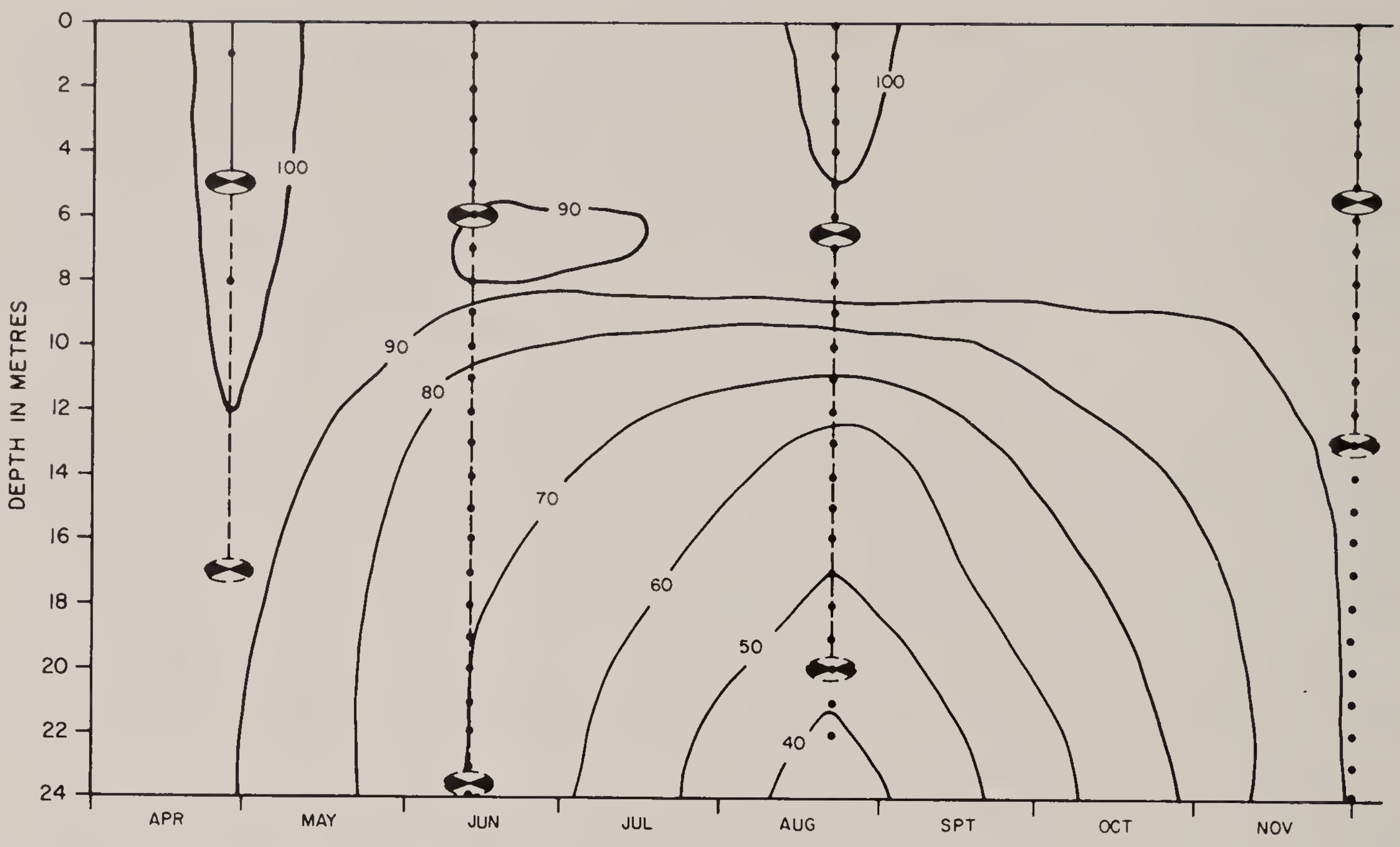

Fig 2 Third Lake 1983, isopleths for % oxygen saturation and actual (—) and theoretical (--) Secchi readings.

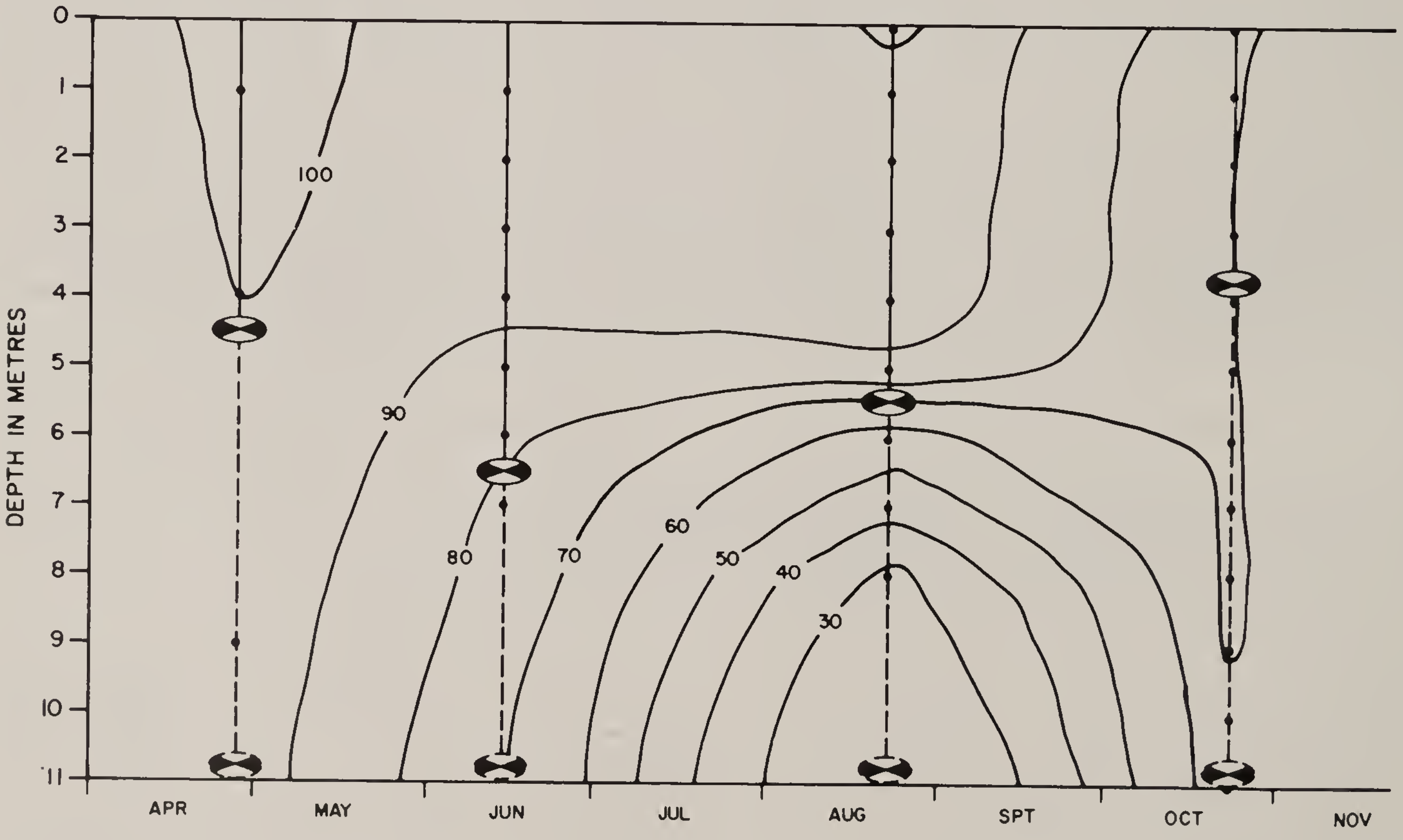

Fig 3 Three Mile Lake 1983, isopleths for % oxygen saturation and actual (—) and theoretical (--) Secchi readings.

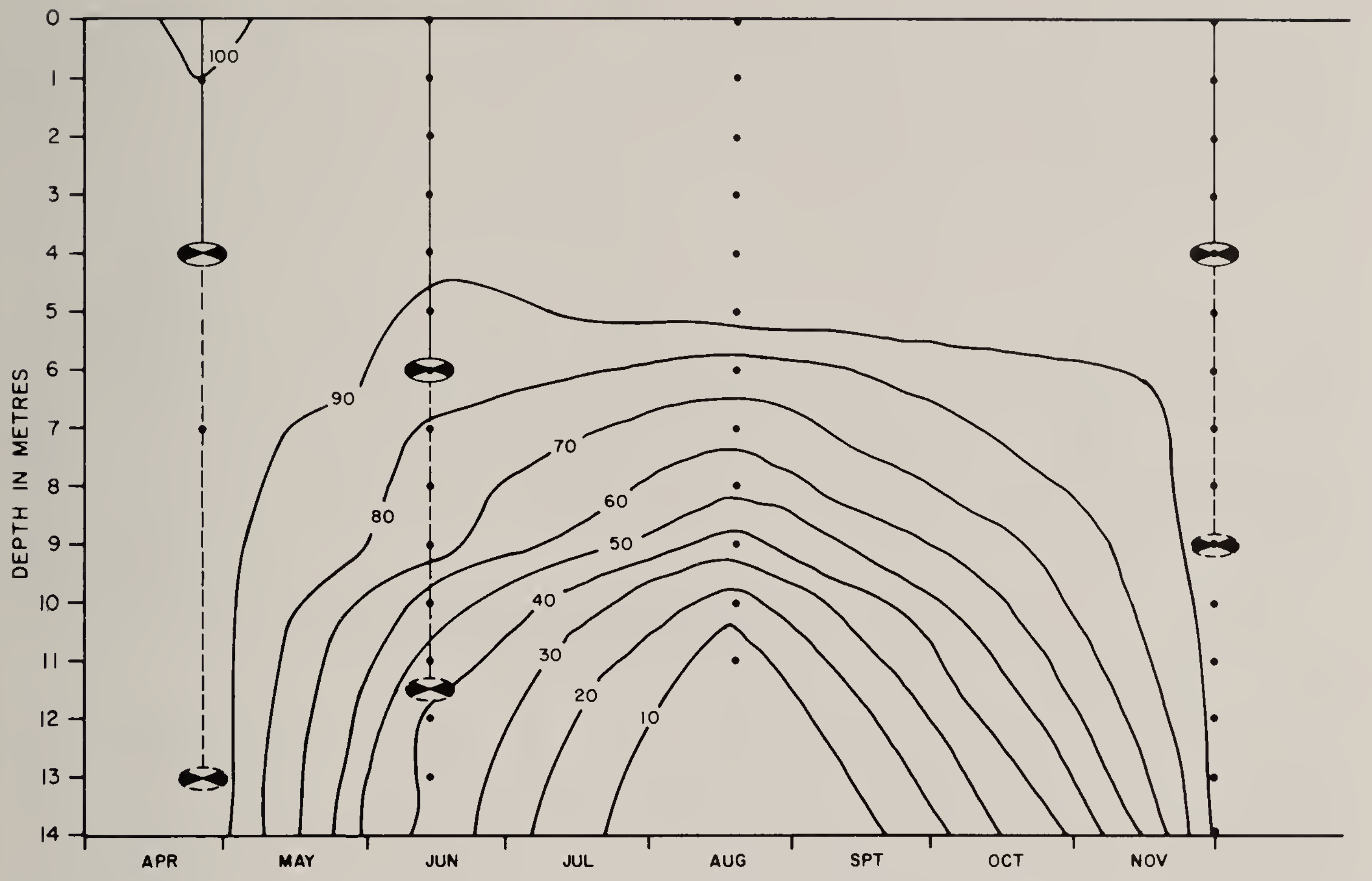

Fig 4 Powder Mill Lake 1983, isopleths for % oxygen saturation and actual (—) and theoretical (--) Secchi readings.

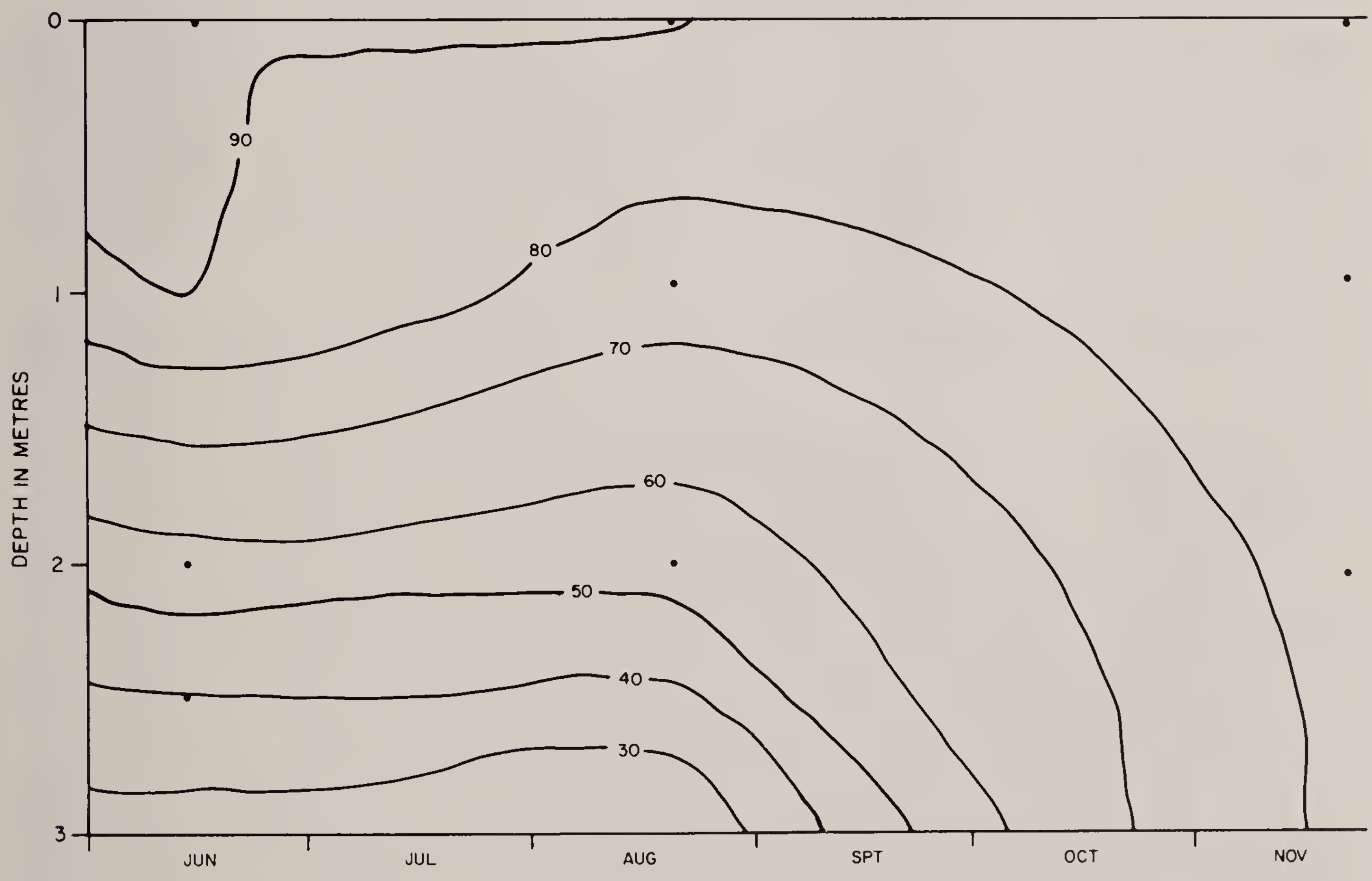

Fig 5 Muddy Pond 1983, isopleths for % oxygen saturation and actual (—) and theoretical (--) Secchi readings.

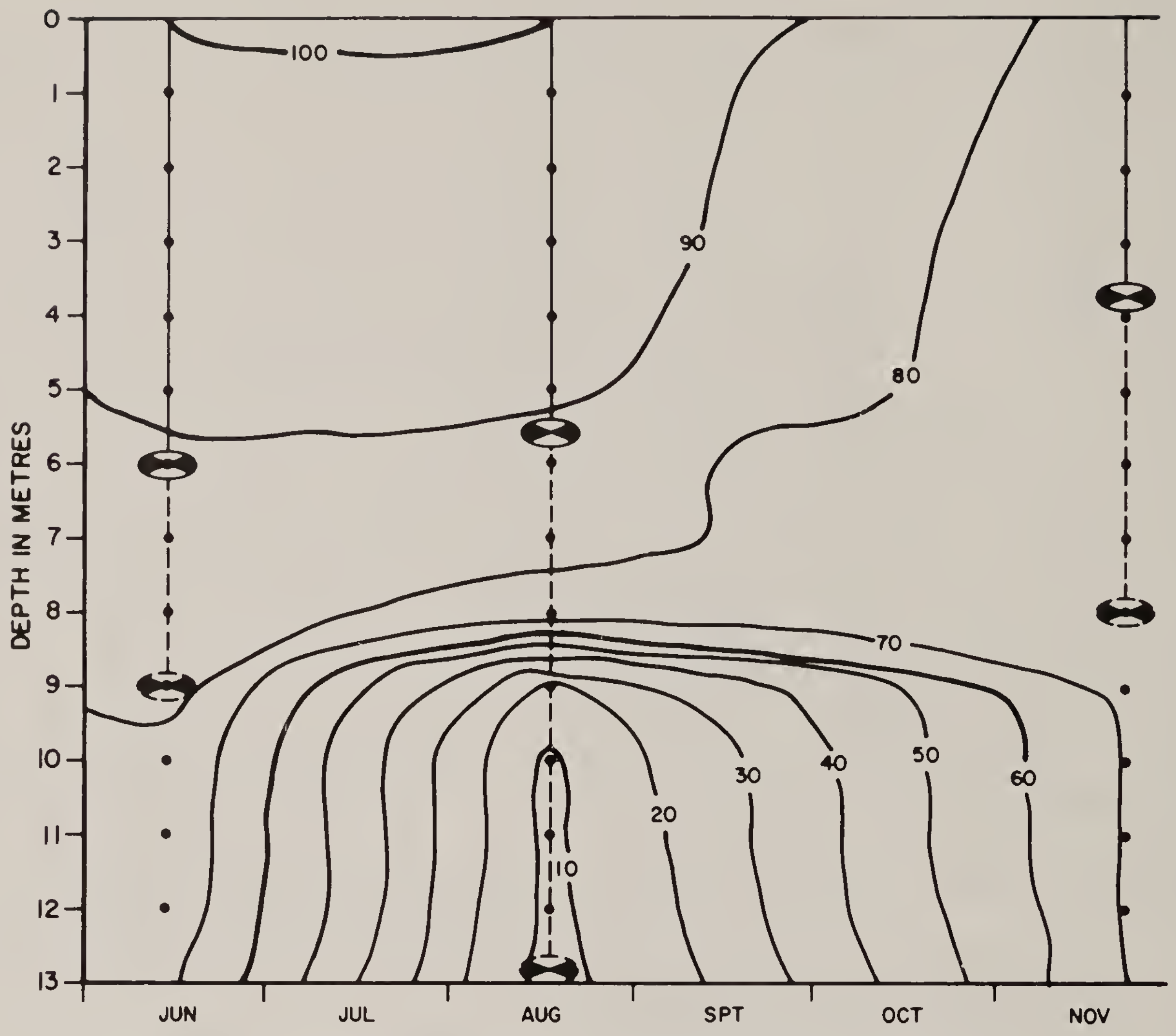

Fig 6 Lake Thomas 1983, isopleths for % oxygen saturation and actual (—) and theoretical (--) Secchi readings.

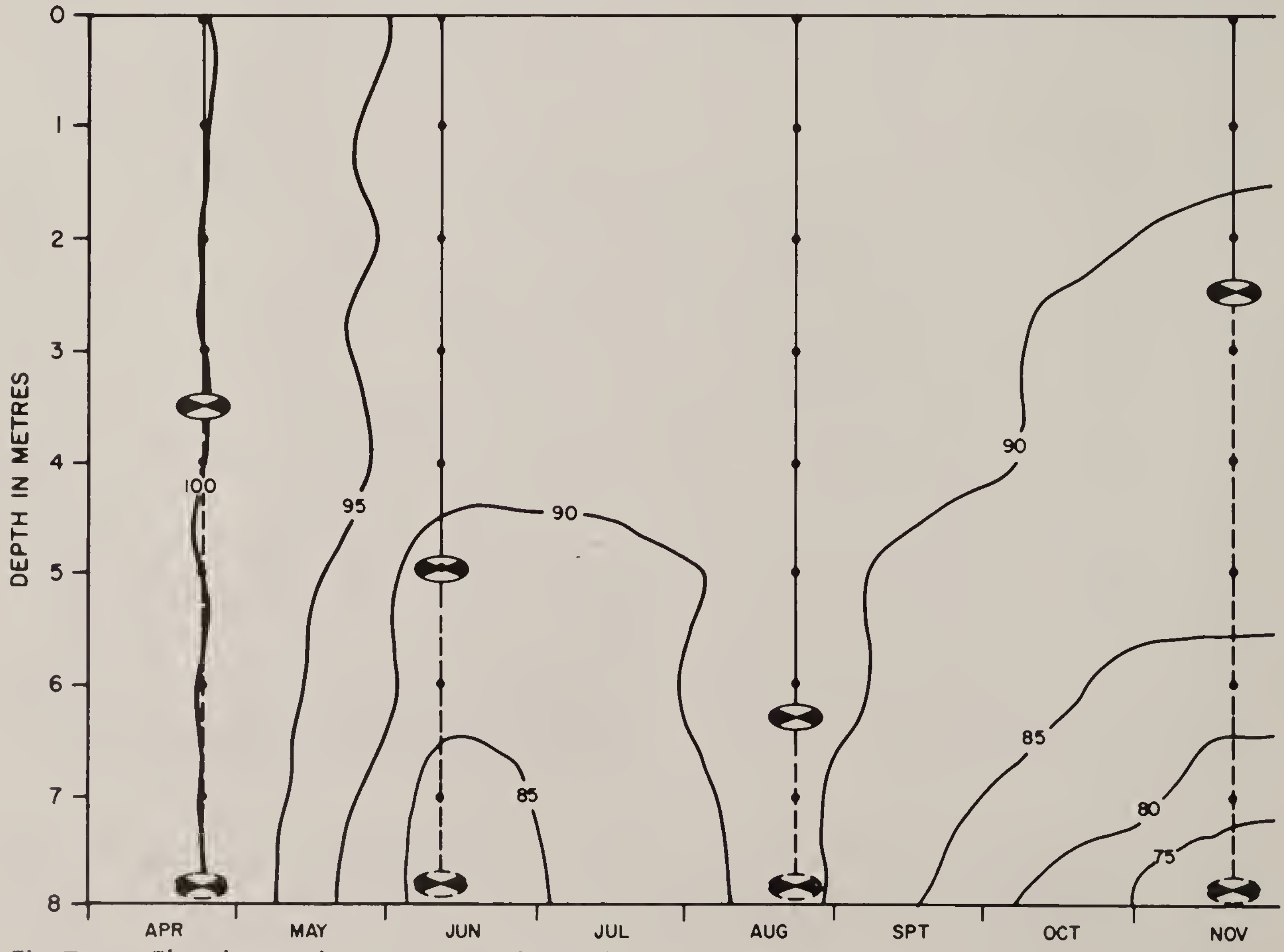

Fig 7 Fletcher Lake 1983, isopleths for % oxygen saturation and actual (—) and theoretical (--) Secchi readings.

than saturation. However, all lakes were above the threshold of 10% oxygen saturation, when a variety of chemical and biological process begin to display adverse effects (Chapra and Dobson 1981). The rapid flushing rate of Fletcher Lake (35 times per annum) kept oxygen saturation greater than 75% during the entire study period. Lakes Powder Mill and Thomas showed hypolimnetic oxygen deficits to as low as 10% of saturation during the summer months.

Thienemann Classification of Lake Trophic Status

Thienemann classification of lake trophic status is based on the oxygen depletion rates in the hypolimnion, initial oxygen concentrations at Spring turnover and the duration of thermal stratification (Chapra and Dobson 1981).

The Thienemann index was calculated for lakes Powder Mill, Thomas, and Third. The first two lakes were found to have low levels of oxygen in the hypolimnion during mid-summer.

The Thienemann index, TI_T can be expressed as:

$$TI_T = 11.1 \times \frac{Dv\, t_s}{C_i} \qquad (2)$$

where Dv is the volumetric oxygen depletion rate expressed in $mg.L^{-1}$ per month, t_s is the duration of the stratified period in months, and C_i is the oxygen concentration at the onset of stratification expressed in $mg.L^{-1}$ (Chapra and Dobson 1981). A Thienemann index between 0 and 5 indicates oligotrophy, between 5 and 10 mesotrophy and above 10 eutrophy. The duration of thermal stratification in the lakes was estimated at five months. The sampling schedule did not permit a more precise delineation of autumn turnover in the study lakes.

According to Thienemann index both Third and Powder Mill Lakes are considered mesotrophic, Lake Thomas eutrophic (Table IV), its Thienemann index being similar to that calculated for Central Erie (Chapra and Dobson 1981). The classification of the study lakes by the Thienemann index placed the lakes in a higher trophic status than the OECD phosphorus classification. This difference could be generated by the over-estimation of the stratification period for the study lakes, although basin morphometry also influences oxygen depletion rates (Hutchinson 1957).

Table IV Nova Scotian and Great Lakes data relevant to oxygen depletion along with calculated values of the Thienemann index.

Lake or basin	Thickness of Hypolinnion (m)	Volumetric oxygen depletion rate ($mg.L^{-1}.mo^{-1}$)	Initial oxygen con. ($mg.L^{-1}$)	Duration* of stratification (mo)	Thienemann** index, TI_T
Third	15	1.3	12	5*	6.0
Powder Mill	5	1.46	11	5*	7.4
Thomas	5	2.6	11*	5*	13.1
Superior	134	0.14	13	3.5	0.4
Huron	50	0.24	13	4.0	0.8
Central Erie	3.9	3.2	11	4.0	12.9
Eastern Erie	14.7	1.73	12	4.5	7.2
Ontario	71	0.33	13	4.5	1.3

* Estimated
** 0 - 5 oligotrophic, 5 - 10 mesotrophic, 10+ eutrophic

Trophic Classification by Lake Transparency

Actual and theoretical Secchi depth are presented in Fig. 2, 3, 4, 6, and 7. The theoretical Secchi depth was obtained by transposing point locations on phosphorus probability curves to Secchi probability curves (Vollenweider and Kerekes 1980). Theoretical Secchi depths were then interpolated from the abcissal axis on the Secchi curve. Mean annual Secchi depths were calculated from the four readings taken at each lake during the study period, except for Lakes Powder Mill and Thomas where only three readings were taken. The average was then used to classify each lake based on Secchi disc transparency.

The average Secchi depth for study lakes was 5 m, which was greater than the 3 m average found for a study of 288 lakes in the province (Underwood unpublished data). However, the actual Secchi depths were always lower than the theoretical value, and based on Secchi disc transparency, all study lakes were classified mesotrophic.

Table V Comparison of trophic classifications based on phosphorus, secchi and oxygen.

Lake Name	Trophic classification based on phosphorus	Trophic classification based on Secchi	Trophic classification based on Thienemann's oxygen index
Third Lake	Ultra-oligotrophic	Mesotrophic	Mesotrophic
Three Mile	Oligotrophic	Mesotrophic	
Powder Mill	Oligotrophic	Mesotrophic	Mesotrophic
Perry	Oligotrophic		
Muddy Pond	Mesotrophic		
Thomas	Oligotrophic	Mesotrophic	Eutrophic
Fletcher	Oligotrophic	Mesotrophic	

Discussion

Comparison of Trophic Indices Used

The trophic states of the studied lakes were determined by three techniques: mean annual phosphorus concentrations; Secchi disc transparencies; and hypolimnetic oxygen depletion rates. The results of the comparison are shown in Table V. Classifications of trophic states of the lakes based on Secchi disc transparency and oxygen depletion are similar but result in higher estimates of eutrophy than classifications based on phosphorus concentrations.

Phosphorus concentrations have been widely used to estimate the degree of eutrophication experienced in a water body, but are complex and expensive compared to the other limnological measurements used in this study. One drawback of the phosphorus probability index is that it does not fully accommodate differences in sizes of hypolimnions, and consequent relative demands on available oxygen supplies in deeper waters. This could influence both the availability of cool mid-summer refugia for poikilotherms, and recycling of toxic metals from sediments.

Measurement of Secchi disc transparency in order to ascertain trophic conditions, although not as sound as the phosphorus method, produced results that were comparable to the calculated Thienemann index. This method is not only simple but inexpensive, requiring only the use of a boat and a Secchi disc. Since the average Secchi disc reading is used to assign a trophic status, frequent readings are necessary during the study period. Factors that affect turbidity other than plankton growth, such as suspended material due to siltation from high runoff, would alter the findings. Highly colored water would also impair reliability of the Secchi index.

Determination of hypolimnetic oxygen depletion rates, provides another method of trophic classification, while remaining relatively simple and inexpensive. Delineation of the stratification period plays a very important role in arriving at the proper index, and it is necessary to take oxygen measurements with almost the same frequency as samples for phosphate analysis. For example, if a stratification period of 3 months is assumed for Third Lake, the resultant Thienemann index is 3.6 which is the oligotrophic range. A further note of caution is that oxygen depletion can be misleading if the water color is greater than about 10. Humic substances contribute to oxygen depletion in the hypolimnion, which can be incorrectly interpreted as oxygen depletion resulting from organic matter produced within the lake (Kerekes 1974). Color was low in Third, and Thomas lakes, but exceeded 35 in Muddy Pond.

Another important consideration in using the Thienemann index is lake morphology, as this controls the ratio of the volume of the epilimnion to the hypolimnion. The bottom waters of a deep stratified lake would therefore have a greater supply of oxygen than those of a shallower stratified lake (Hutchinson 1957).

As we had no chlorophyll data for comparison, it is inappropriate to recommend one of the three indices as best choice. But even if that measure of production of autochthonous carbon were available it fails to account for oxygen stress resulting from inputs of allochthonous carbon. Perhaps the most satisfactory application of indices would be to develop a method of averaging them in order to produce a type of composite index (cf. Carlson 1977). The use of a single index could result in misinterpretation of water quality in our local lakes.

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References

Anonymous. 1981. Final report: Shubenacadie - Stewiacke River Basin Board. Nova Scotia Government Bookstore, Halifax. B3J 3T3.

Carlson, R.R. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22:361-369.

Chapra, S.C. and **Dobson, H.F.H.** 1981. Quantification of the lake typologies of Naumann (surface quality) and Thienemann (oxygen) with special reference to the Great Lakes. J. Great Lakes Res. 7: 182-193.

CNC/IHD (Canadian National Committee for the International Hydrological Decade). 1978. Hydrological Atlas of Canada. Printing and Publishing Supply and Services Canada, Ottawa, K1A 0S9.

Fricker, H. 1981. *Critical evaluation of the application of statistical phosphorus loading models to Alpine lakes.* Ph.D. Thesis, Swiss Federal Institute of Technology, Zurich, ADAG Administration and Druck AG.

Hart, W. 1979. Environmental assessment of surface waters in the vicinity of Third Lake. Prepared for: Project Planning Consultants Ltd. by: Geolimnos Consulting.

Hart, W., Scott, R. and **Ogden, J.G., III.** 1978. A phosphorus loading model for lakes in the Shubenacadie headwaters. Technical Report No. 2, The Shubenacadie Stewiacke River Basin Board, Nova Scotia Department of the Environment.

Hutchinson, G.E. 1957. *A treatise on limnology.* John Wiley and Sons, Inc. New York.

IWD (Inland Waters Directorate). 1974. Shubenacadie Headwaters Environmental Survey. Draft. Sector Report 4, Water Resources. Environment Canada.

Johnson, P. 1978. Water quality of ten Shubenacadie headwater lakes: A preliminary assessment. Shubenacadie - Stewiacke River Basin Board Tech. Rep. No. 14, Nova Scotia Department of the Environment.

Kerekes, J. 1983. Predicting trophic response to phosphorus addition in a Cape Breton lake. Proc. N.S. Inst. Sci. 33: 7-18.

Kerekes, J. 1974. Limnological conditions in five small oligotrophic lakes in Terra Nova National Park, Newfoundland. J. Fish. Res. Board. Can. 31: 555-583.

Mudroch, A. and **Sandilands, R.** 1978. Geochemical analyses of lake bottom sediments in the Shubenacadie headwaters. Technical Report No. 9, The Shubenacadie - Stewiacke River Basin Board, Nova Scotia Department of the Environment.

Ogden, J.G., III. 1972. MAPC 71-72, Water quality survey for selected metropolitan area lakes. Task group on Water Supply and Waste Disposal, Metro Area Planning Committee, Halifax, N.S.

Vallentyne, J.R. 1974. *The algal bowl, lakes and man.* Miscellaneous Special Publication 22. Department of the Environment, Fisheries and Marine Service, Ottawa.

Vollenweider, R.A. and **Dillon, P.J.** 1974. The application of the phosphorus loading concept for eutrophication research. Canada Centre for Inland Waters, Environment Canada, Burlington, Ontario.

Vollenweider, R.A. and **Kerekes, J.** 1980. *Synthesis report (draft). Cooperative programme on monitoring of inland waters (eutrophication control).* Rep. Technical Bureau, Water Management Sector Group, Organization for Economic Cooperation and Development (OECD), Paris.

Water Resources Branch. 1984. Surface runoff for Shubenacadie headwaters June 1983 to March 1984. Inland Waters Directorate, Environment Canada, Dartmouth, N.S.

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SOME ASPECTS OF THE CHEMISTRY AND BIOLOGY OF THE GENUS HYPOCREA AND ITS ANAMORPHS, TRICHODERMA AND GLIOCLADIUM

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The literature describing the occurrence, some aspects of the physiology and toxicology of the metabolic products of *Hypocrea*, *Gliocladium* and *Trichoderma* spp. is reviewed. A list of known metabolites of this group of fungi has been assembled and the common physical properties of these compounds are given when they have been reported. Such data as have been published on the toxicity of these metabolites is summarised, with particular emphasis on suitable review articles. An attempt is made to provide a comprehensive list of agents, known as potential inhibitors of the growth of these fungi.

La littérature décrivant quelques aspects de la physiologie et de la toxicologie des métabolites *d'Hypocrea*, *Gliocladium* et *Trichoderma* spp. est passée en revue. Une liste des metabolites connus de ce groupe de moisissures est dressée et les propriétés physiques courantes sont données si connues. Les informations publiées concernant la toxicité de ces mètabolites sont resumées avec reference aux articles de revue appropriées. L'auteur tente de donner une liste compréhensive des agents potentiellement inhibiteurs de la croissance de ces moisissures.

Introduction

The taxonomy of the three genera, *Hypocrea*, *Gliocladium*, and *Trichoderma* is in some respects confused. Authoritative studies of these taxonomic problems may be found in Gams (1971), Webster and Lomas (1964) and Rifai (1969), but there are many examples in the literature that report difficult classification problems (e.g. Brian 1944, Brewer and Taylor 1981). For the purpose of this review, therefore, the position is taken that the three genera are very closely related and that serious lacunae would appear should one or other be excluded. There is also some debate concerning the classification of the fungus that produces cyclosporins; it was originally thought to be *Trichoderma polysporum* but later work has used the name *Tolypocladium inflatum* (Gams 1971b). For the purpose of the review it is assumed that the taxonomy remains uncertain.

The first part of the review is devoted to the substrates on which the organisms are found, with emphasis on the more unusual of these; the second part attempts to give a comprehensive account of the very wide variety of known metabolites and the third part describes what is known of their toxicities. These fungi are heavily involved in the natural degradation of organic substrates and hence a very large body of work has been done in attempts to protect e.g. wood from their activities. The fourth part of the review is therefore devoted to a description of the agents that have been used to this end and to their effectiveness.

The literature has been thoroughly searched up to and including December 1984, but additional references from 1985 will be found where these have come to my attention during that year. I have not read all the papers cited in this review; articles that I have not read can be distinguished by a reference to Chemical Abstracts.

NRCC No. 26328

Natural and unusual habitats of fungi of the genera Hypocrea, Gliocladium and Trichoderma

Hypocrea spp. are usually found on decaying wood but it has been known for more than 100 years that frequently they are parasites on other fungi (see e.g. Saccardo 1883, Tabata and Kondo 1977). By contrast the genera *Gliocladium* and *Trichoderma* are found very frequently in the soils of the planet. There have been a number of extensive studies of the soil ecology of these organisms. For example, Berestetskii, Patyka and Nadkernichuyi (1977) studied more than 700 isolates of *Trichoderma* from soils and Brewer and Taylor (1980) found that *Gliocladium roseum, Trichoderma koningii* and *Trichoderma hamatum* accounted for about 6% of some 25,000 fungal isolates collected over a 10 year period from pasture soil at Nappan, Nova Scotia. Many of the species of the three genera are capable of the hydrolysis of plant polysaccharides, especially cellulose, and a very large number of studies of this process both at the cellular and enzymic levels has been recorded in the literature. The impetus behind this work is the conversion of plant waste e.g. coffee grounds (Aguirre *et al.* 1976) into digestible components e.g. fructose in the diet of humans and domestic animals. This topic has been reviewed on many occasions and is not repeated here; the interested reader should consult for example Ryu and Mandels (1980).

The substrates on which these fungi have been observed to grow are given in Table I. It is clear from the data in the Table that these organisms can grow on a diverse range of substrates from stainless steel (Brown and Pabst 1977), presumably with a carbon content to bitumen used for road construction (Khimerik and Koval 1977). However a ubiquitous substrate for most of these fungi is wood and the various products manufactured from it (Merrill *et al.* 1965). Viable *Trichoderma* spp. have been found in thin cross-sections of timber (Dinulescu 1979) and this is perhaps not surprising because of the growing appreciation of the importance of endophytic fungi in higher plants (Claydon *et al.* 1985). The economic losses resulting from fungal degradation of timber and associated products has led to considerable effort to control their growth on this substrate. This aspect is discussed in greater detail in a later part of the review, but it is relevant to mention at this point that alkali treatment of wood chips before storage (Bergman and Nilsson 1971) was not particularly effective and that fumigation with formaldehyde resulted in the discovery that this agent (and other C_1 compounds) were utilised by *Gliocladium deliquescens* with alacrity (Sakaguchi *et al.* 1976). It is known (Moelhave 1977) that the formaldehyde concentration in aggregated wood products cemented with urea-formaldehyde resins is proportional to the humidity; that *Trichoderma* spp. grown on such resins (von Kerner-gang and Hoffmann 1982) and hence it may be concluded that these fungi are natural components of all materials containing products derived from wood. Laboratory studies (Gauze *et al.* 1983, Brewer *et al.* 1982, Sierota 1977) have shown that these fungi grow well on very simple media containing only one of a wide range of carbohydrate sources, and simple nitrogen containing compounds e.g. urea (Nelson 1972, 1976). It follows that these organisms will grow rapidly on almost any natural substrate providing that both the temperature and humidity conditions are suitable. Little is known of the range of humidities conducive to growth (but see Widden and Abitol 1980); much more is known about the temperature range (Brewer and Taylor 1980) which is relatively wide (5-35°).

Metabolites of fungi of the genera Hypocrea, Gliocladium and Trichoderma

For the purpose of this review, the metabolic products of these fungi are separated into groups; the grouping is based on the chemistry of the metabolites and particularly on their probable mode of biosynthesis. The appearance of a compound (or a mixture of very closely related compounds) in one of the Tables implies that there

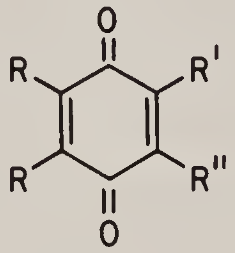
Table I Substrates supporting growth of *Hypocrea* spp. *Gliocladium* spp. or *Trichoderma* spp.

Organism	Substrate	Reference
Hypocrea nigricans	Lentinus edodes	Tabata & Kondo (1977)
	Cellulose	Doi *et al.*, (1972)
Hypocrea peltata	Cellulose	Doi *et al.*, (1972)
Hypocrea schweinitzii	Lentinus edodes	Tabata & Kondo (1977)
Gliocladium sp.	Groundnut	Madaan & Chohan (1978)
	Epichlorhydrin cross-linked cellulose	Dao Cong Dan *et al.*, (1980)
Gliocladium varians	Rhizospheres of barley & oats	Sukhorukova (1972)
Trichoderma spp.	Barley β-glucan	Igaue (1966)
	Cork	Cook & Harrington (1948)
	Lentinus edodes	Tabata & Kondo (1977)
	Rhizoctonia spp.	Allen & Haenseler (1935)
	Phythium spp.	Haenseler & Allen (1934)
	Petroleum waxes	Bilai *et al.*, (1965)
	Motor oil recovered from Chesapeake Bay	Colwell *et al.*, (1974)
	Road building bitumen	Khimerik and Koval (1977)
	Polyvinyl chloride/dibutyl sebaccite/dioctyl phthalate	Berk (1951)
	Polyvinyl chloride	Yamano (1979)
	Polyvinyl alcohol based polymer	Shteinberg *et al.*, (1983)
	Acetylated cellulose	Abramova *et al.*, (1973)
	Ethylene/vinyl acetate copolymers	Griffin and Mivetchi (1977)
	Paint	Kleus and Lang (1956)
	Organosilicon protective coatings	Pashenko *et al.*, (1978)
	Chromed leather (N. American)	Mitzutani *et al.*, (1980)
	Wood shavings impregnated with urea	Nelson (1972)
	Silicate rocks and soil	Henderson and Duff (1963)
	Stainless steel and aluminum alloys	Brown & Pabst (1977)
	Domestic humidifiers	Burge *et al.*, (1980)
Trichoderma hamatum	Diesel fuel	Suess & Netzsch-Lehner (1969)
Trichoderma harzianum	Lentinus edodes	Tabata & Kondo (1977)
	Ferric hydroxide mud impregnated with oil	Gudin and Chater (1977)
Trichoderma koningii	Wood pulp	Wakazawa *et al.*, (1965)
Trichoderma lignorum	Rhizoctonia solani	Weindling (1932) Daines (1937)
	Phytophthora parasitica	Weindling (1932)
Trichoderma lignorum	Sclerotium rolfsii	Weindling (1932)
	Pythium sp.	Weindling (1932)
	Rhizopus spp.	Weindling (1932)
	Actinomyces scabies	Daines (1937)
	Wood resin	Nilsson and Assarsson (1970)
	Diglycidyl-hydroquinone ether polymers	Anisimov *et al.*, (1977)
Trichoderma viride	Wood	Stranks (1971)
	Wood	Verrall (1949)
	Chitin	Kawasaki and Ito (1966)
	Rye-grass straw	Han and Anderson (1975)
	Synthetic rubbers and polyethylene	Mazur (1979)
	Vanillin	Moreau and Augier (1962)
	Allyl alcohol	Jackson (1973)

exists in the literature, data from the measurement of physical properties that allow competent chemists to judge if natural products they isolate are identical or not. A few other materials that have been reported in Abstracts in papers I have been unable to read are reported in the text. In addition, such simple volatile metabolites - ethyl alcohol, ethyl acetate, sec-butyl alcohol, isoamyl alcohol, octanol, octa-3-one, oct-1-ene-3-ol (Saito *et al.* 1981) and acetaldehyde (Dennis and Webster 1971) have not been included in the Tables. The biological significance of the production of volatile metabolites by these fungi have interested mycologists for many years (Bilai 1956, Hutchinson and Cowan 1972, Tamimi and Hutchinson 1975). This has been particularly the case because of the part that may be played by such metabolites in the sexual reproductive cycle of many Phytophthora spp. (Reeves and Jackson 1972, Pratt *et al.* 1972); species responsible for diseases in some of the world's most important agricultural crops. However a systematic examination of a large number of isolates for volatile metabolites has not been recorded. Reference to the melting points given in the Tables shows that many metabolites have melting points below 150° - all such compounds can be considered to have measurable vapour pressures.

Polyketide metabolites produced by Hypocrea, Gliocladium and Trichoderma

A list of these compounds is given in Table II. Apart from the bis-anthraquinone (XXXIII) most of these compounds were studied in the era 1950-1965 i.e. before the advent of high pressure liquid chromatography. It is likely that there are many more variations in the resorchinol (Pettersson 1965) and hydroquinone (Brian *et al.* 1951, Vischer 1953) components than those recorded in the Table. The benzoquinones, and anthraquinones are easily reduced to the leuco forms and strong evidence has been presented (Pettersson 1965) that these are the true natural products - the more volatile quinones being artefacts of the isolation procedure. Such compounds are, of course, vat-dye stuffs, or in other words they form stable complexes with natural carbohydrate polymers. Most of these compounds are biosynthesised, often in high yield, from acetate by a polyketide route and are formed after the end of the so-called logarithmic phase of growth, usually when all source of nitrogen has been exhausted (Pettersson 1965, Gatenbeck 1958). The diphenyl ether metabolites (XXXI) isolated



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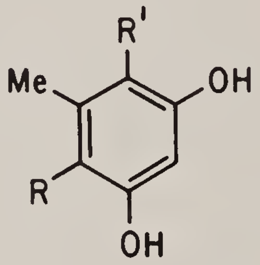

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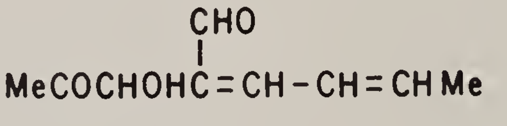
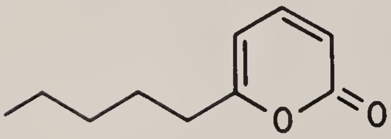
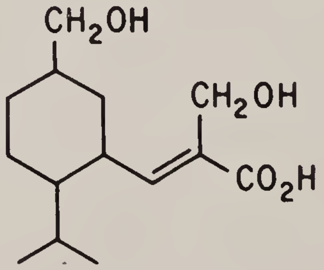


$$\mathrm{MeCOCHOH}\overset{\mathrm{CHO}}{\overset{|}{\mathrm{C}}}\mathrm{=CH-CH=CHMe}$$

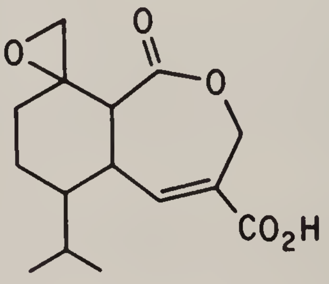
III



IV



V



VI

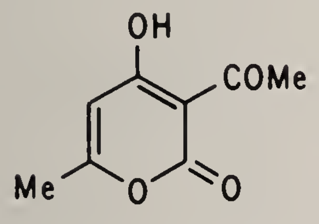
Table II Polyketide metabolites of Hypocrea spp., Gliocladium spp. and Trichoderma spp.

Trivial name	Structure	m.p.	Producing organism	References
Tartronic acid	$HOCH(CO_2H)_2$	158-60°	T. pseudokoningii	Kamal *et al.*, (1971)
Aurantiogliocladin	I, R=Me, R′=R″=OMe	63°	G. roseum	Brian *et al.*, (1951)
Gliorosein	Dihydro I, R=Me, R′=R″=OMe	48°		
	I, R=Me, R′=R″=OH	182°		Pettersson (1964)
	I, R=Me, R′=OH, R″=OMe	70°		
	I, R=OMe, R′=R″=H		T. pseudokoningii	Kamal *et al.*, (1971)
Orcinol	II, R=R′=H	108°	G. roseum	Pettersson (1965)
	II, R=Me, R′=H	136°		
	II, R=Me, R′=CO_2H	158°		
Dehydroacetic acid	XXX	109-11°	H. sulphurea	Nair and Carey (1979)
	XXXI, R=H		H. citrina	
	XXXI, R=CO_2H	194°		
Pachybasin	XXXII, R=R^3=H, R^1=OH, R^2=Me	176°	T. viride	Slater *et al.*, (1967)
Chrysophanol	XXXII, R=R^1=OH, R^2=Me,	194°		
	R^3=H		H. austragrandis	Nago and Ishikawa (1970)
Emodin	XXXII, R=R^1=R^3=OH, R^2=Me	256-8°	T. viride	Slater *et al.*, (1967)
			H. austragrandis	Nago and Ishikawa (1971)
Hypochrysophanol	unknown	205°		
SC2051	XXXIII		Trichoderma sp.	Manyu (1980)
	IV, x=CH=CH		T. viride	Moss *et al.*, (1975)
	IV, x=Ch_2-CH_2			Collins and Halim (1972)
			Trichoderma sp.	Kikuchi *et al.*, (1974)

Table III Terpenoid metabolites of Hypocrea spp., Gliocladium spp. and Trichoderma spp.

Trivial name	Structure	m.p.	$[\alpha]_D$	Producing organism	References
	3-Hydroxy-3,4-dimethylpentanoic acid	100°/.05 mm	-1.1°	G. deliquescens	Hanson and O'Leary (1981)
(+)-R-avellaneol	III		+39°	H. avellania	Ananthasubramanian *et al.*, (1978)
Gliocladic acid	V			G. virans T. viride	Itoh *et al.*, (1982)
Heptelidic acid = avocetin	VI	62-5°	+7.4°	G. virans	Itoh *et al.*, (1980) Stipanovic and Howell (1983)
Cyclonerodiol	VII		-20°	T. polysporum	Fujita *et al.*, (1984)
Cyclonerodioloxide	VIII	47-50°	-20°		
Trichodermin = WG 696	IX, $R=R'''=H, R'=Me, R''=OAc$	46°	-11°	T. viride T. polysporum T. sporulosum H. austrograndis	Godtfredson and Vangedal (1965) Adams and Hanson (1972) Nago and Ishikawa (1971)
Trichodermol = roridin C	IX, $R=R'''=H, R'=Me, R''=OH$	115°	-33°	T. polysporum T. sporulosum	Adams and Hanson (1972)
T_2 toxin	IX, $R=OCOCH_2CHMe_2, R'''=OH, R'=CH_2OAc, R''=OAc$	151-2°	+15°	T. lignorum	Bamburg and Strong (1969)
HT_2 toxin (?)	IX, $R=OCOCH_2CHMe_2, R'=CH_2OAc, R''=R'''=OH$				
Trichodermene A	XX			T. pseudokoningii	Kamal *et al.*, (1971)
Viridin	X, Y=O	245°	-224°	T. viride	Brian *et al.*, (1946) Grove *et al.*, (1965, 1966)
Viridiol	X, Y=H, OH	198-201°			Moffatt *et al.*, (1969)
Pyrocalciferol	XXVI	93-5°	+502°	T. pseudokoningii	Kamal *et al.*, (1971)

from *Hypocrea citrina* (Nair and Carey 1979) are derived from orcinol (II, R=R′=H, Yamamoto *et al.* 1972) and the acid (XXXI, R=CO_2H) has also been isolated from *Aspergillus fumigatus.*



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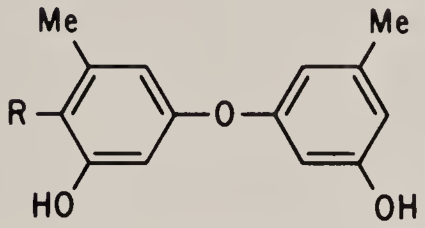
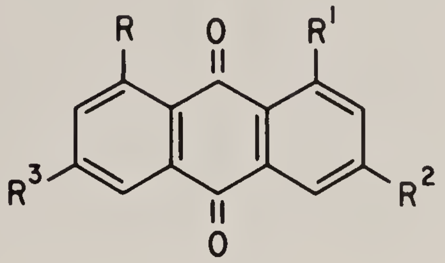
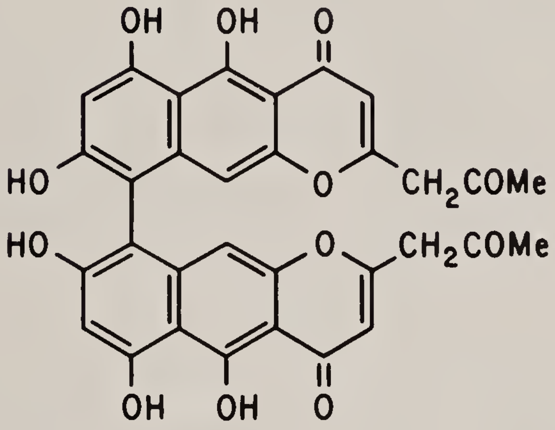


XXXI



XXXII



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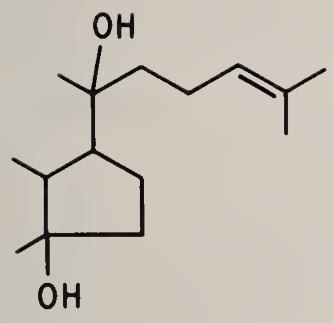

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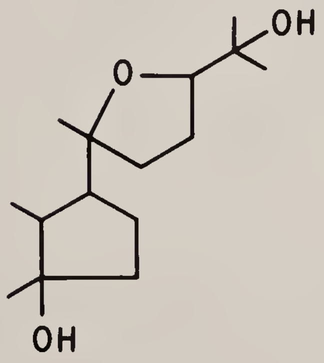

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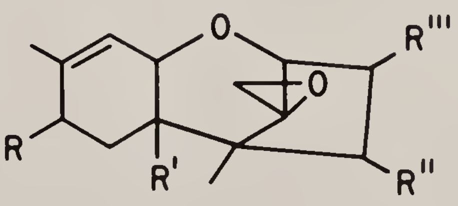

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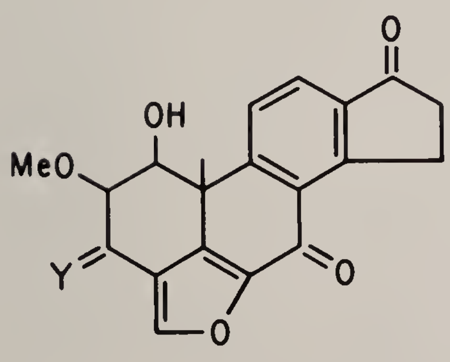

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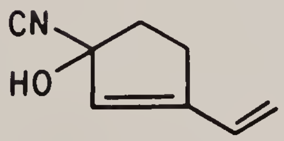
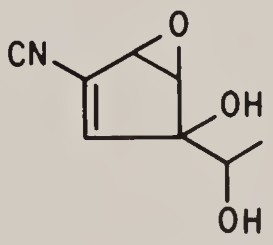


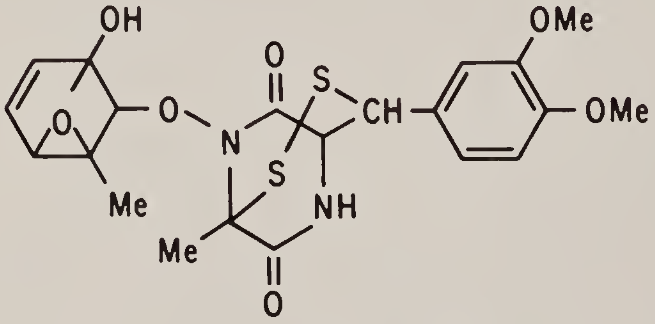
XI



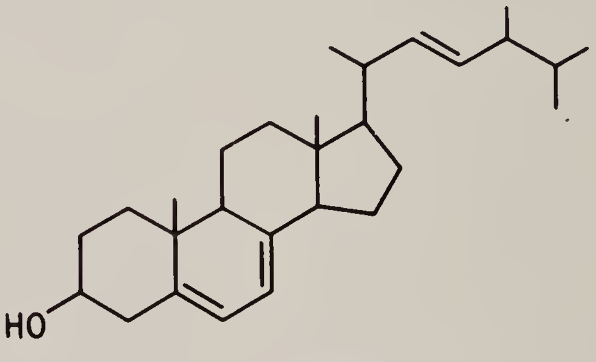
XII

Oligomers of mevalonic acid produced by Gliocladium spp., Hypocrea spp., and Trichoderma spp.

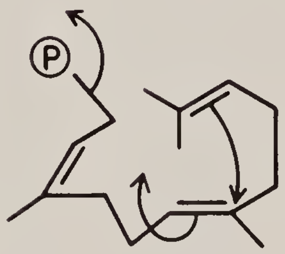
A list of these compounds is given in Table III. Most of the compounds in the Table are low-melting solids. The structures of all, with perhaps the exceptions of avellaneol and trichodermene A have been rigorously established, though the absolute configuration of T_2-toxin and its congeners has not yet been determined. There have been extensive studies on the biosynthesis of trichodermin (IX, R=R‴=H, R′=Me, R″=OAc; Achilladelis *et al.* 1972) and heptelidic acid (VI, Stipanovic and Howell 1983). Both arise from farnesyl pyrophosphate, folded in the same way, but the carbonium ion generated by the leaving pyrophosphate group cyclises in the former case (Arigioni *et al.* 1973) as shown in XXVII and in the latter case as shown in XXVIII. In both cases the following reaction is a hydride shift nominally over 4 carbon atoms in the trichothecin and 3 in the example of heptelidic acid. There is ample precedent for the subsequent rearrangements. It has been suggested (Itoh *et al.* 1982) that gliocladic acid (V) is biodegradatively derived from heptelidic acid by decarboxylation as shown in XXIX. Cyclonerodiol (VII) and its congeners are also known to be sesquiterpenoid (Pitel *et al.* 1971) cyclisation products of farnesyl pyrophosphate.



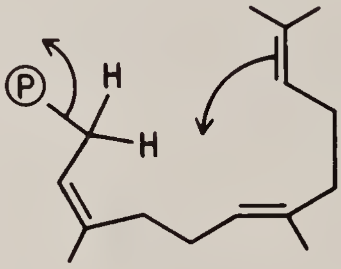
XXV



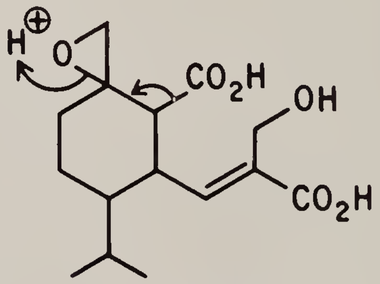
XXVI



XXVII



XXVIII



XXIX

A number of C_{20} and higher oligomers of mevalonic acid are given in Table III of which viridin (X) and its derivatives are perhaps the most interesting. These compounds are not diterpenes but are biodegradation products of steroid intermediates (Blight *et al.* 1968) e.g. lanosterol (Golder and Watson 1980), and squalene (Hanson and Wadsworth 1979). Some work has been done on the biosynthesis of avellaneol (III, Nair *et al.* 1982) who have shown that $^*CH_3CO_2^-$ and $CH_3{}^*CO_2^-$ are recovered in about 2% yield in avellaneol but that $^*CH_3{}^*CO_2^-$ is not incorporated intact. It is therefore possible that the biosynthesis of this metabolite (III) is not terpenoid but is analogous to that of the isocyanides discussed in the next section.

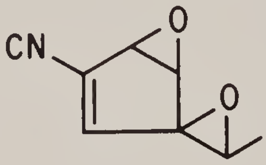
Metabolites derived from α-amino acids by degradation or elaboration

A list of these compounds is given in Table IV. About eight cyclopentyl isocyanides

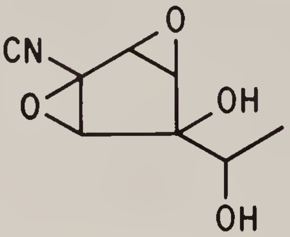
Table IV Non-polypeptide metabolites of Gliocladium spp. and Trichoderma spp. derived from α-amino acids.

Trivial name	Structure	m.p.	$[\alpha]_D$	Producing organism	References
Isonitrin D	XI	55°	+68.5°	T. harzianum	Fujiwara *et al.*, (1982)
Isonitrin B	XII	89°	-89.9°	T. hamatum	
Isonitrin A	XIII	91°	+9°		
Trichoviridin = isonitrin C	XIV	102°	-41.2°	T. viride	Tamura *et al.*, (1975) Nobuhara *et al.*, (1976)
Dermadin	XV	120-5°	+133°	T. hamatum	Brewer *et al.*, (1982)
	XVI				
	XVII				Baldwin *et al.*, (1985)
	XVIII (CO_2Me)				
TP-1		185-7°		T. polysporum	Fujita *et al.*, (1984)
Valinotricin	XIX	128-9°	-65.7°		
	3-Benzyl-6-hydroxymethylenepiperazine-2,5-dione			G. virens	Behling and Fischer (1980)
Gliotoxin	XXI	221°	-255°	G. fimbriatum T. hamatum G. deliquescens	Johnson *et al.*, (1943) Hussain *et al.*, (1975) Hanson and O'Leary (1981)
	XXII, R=H	68-9°	-55.6°		
	XXII, $R=CH_2CH=CMe_2$		-26.8°		
	XXIII (?)				
	XXIV				Kirby *et al.*, (1980)
Gliovirin	XXV	247-9°	-97°	G. virens	Stipanovic and Howell (1982)
	3,6-Dibenzylpiperazine-2,5-dione	303-8°	-167°		
Trichorin A	unknown	234-46°	-190°	Trichoderma sp.	Katayama *et al.*, (1977)
Trichorin B		212-4°			

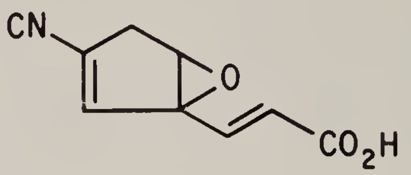
that have been fully characterised, are now known. Their structures are given in formulae XI to XVIII - the latter is only known as its methyl ester, which is not a natural product (Baldwin *et al.* 1985). There are, however, many more such compounds in fermentation broths of *T. hamatum, T. koningii, T. harzianum* and *T. polysporum* and it is likely that many of these will be characterised now that it is possible to obtain stable co-ordination complexes of them with rhodium pentamethylcyclopentadiene isothiocyanate (Hanson *et al.* 1985). The known compounds vary in instability from trichoviridin (XIV) - a stable crystalline solid to 3-(3′-isocyancyclopent-2-enylidene-) propionic acid (XVI), which has a half-life in dilute aqueous solution of pH 8 of about 4 h. All of these compounds are volatile and an early method of recovery was by steam distillation at about 35°/1 mm. These isocyanides are biodegradation products of tyrosine (Baldwin *et al.* 1985, Parry and Hanh Phuoc Buu 1982) and are formed by oxidation of the aromatic ring at the phenolic group, decarboxylation, and cyclisation of the side-chain of the amino acid to provide the cyclopentenyl moiety. This process



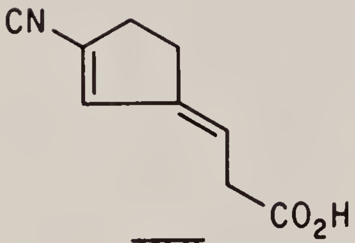
XIII



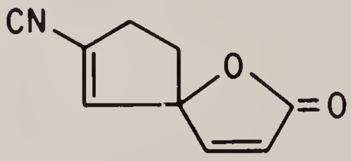
XIV



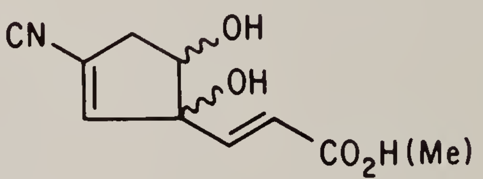
XV



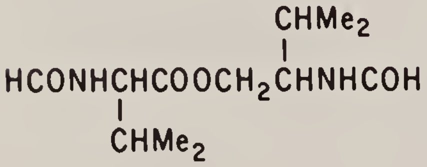
XVI



XVII

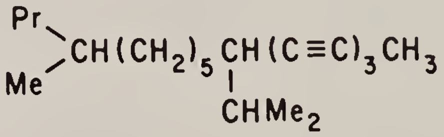


XVIII



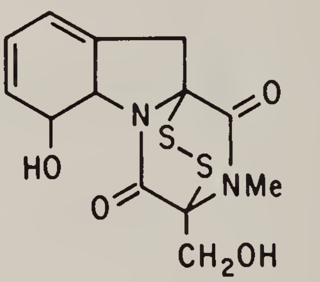
$\mathrm{HCONH\underset{\displaystyle CHMe_2}{CH}COOCH_2\overset{\displaystyle CHMe_2}{CH}NHCOH}$

XIX

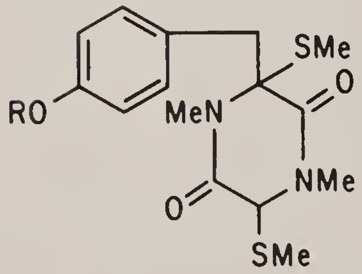


$\begin{matrix}\mathrm{Pr}\\ \mathrm{Me}\end{matrix}\!>\mathrm{CH(CH_2)_5\underset{\displaystyle CHMe_2}{CH}(C{\equiv}C)_3CH_3}$

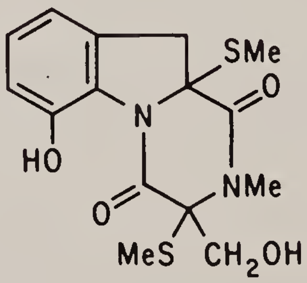
XX



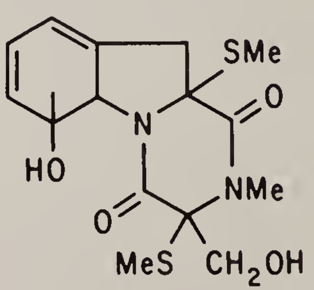
XXI



XXII



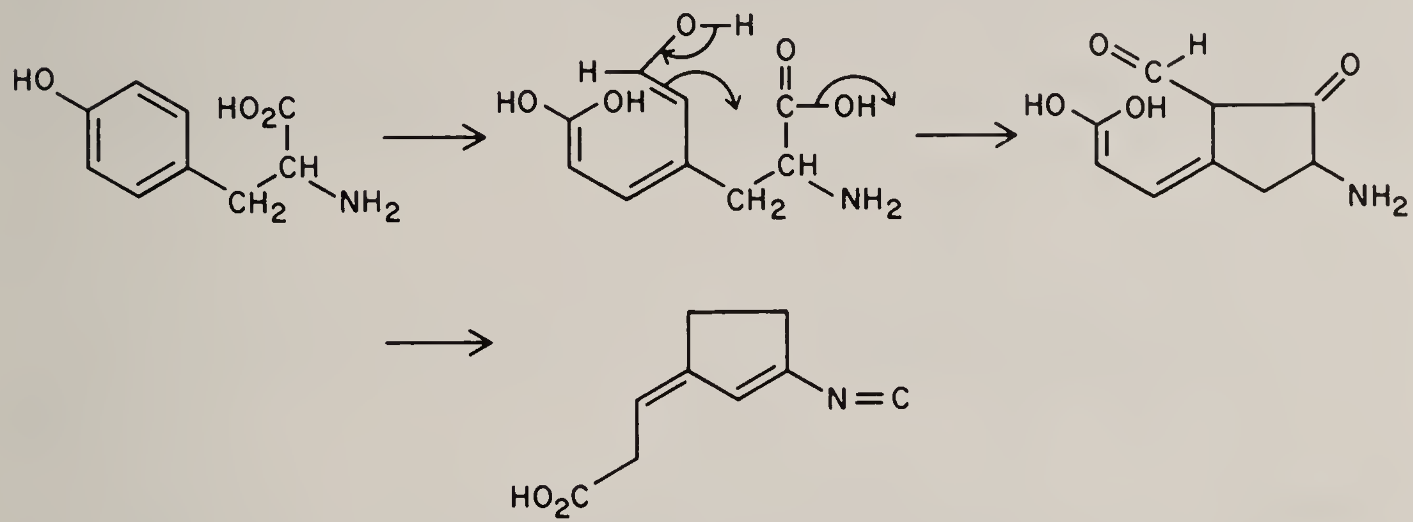
XXIII



XXIV

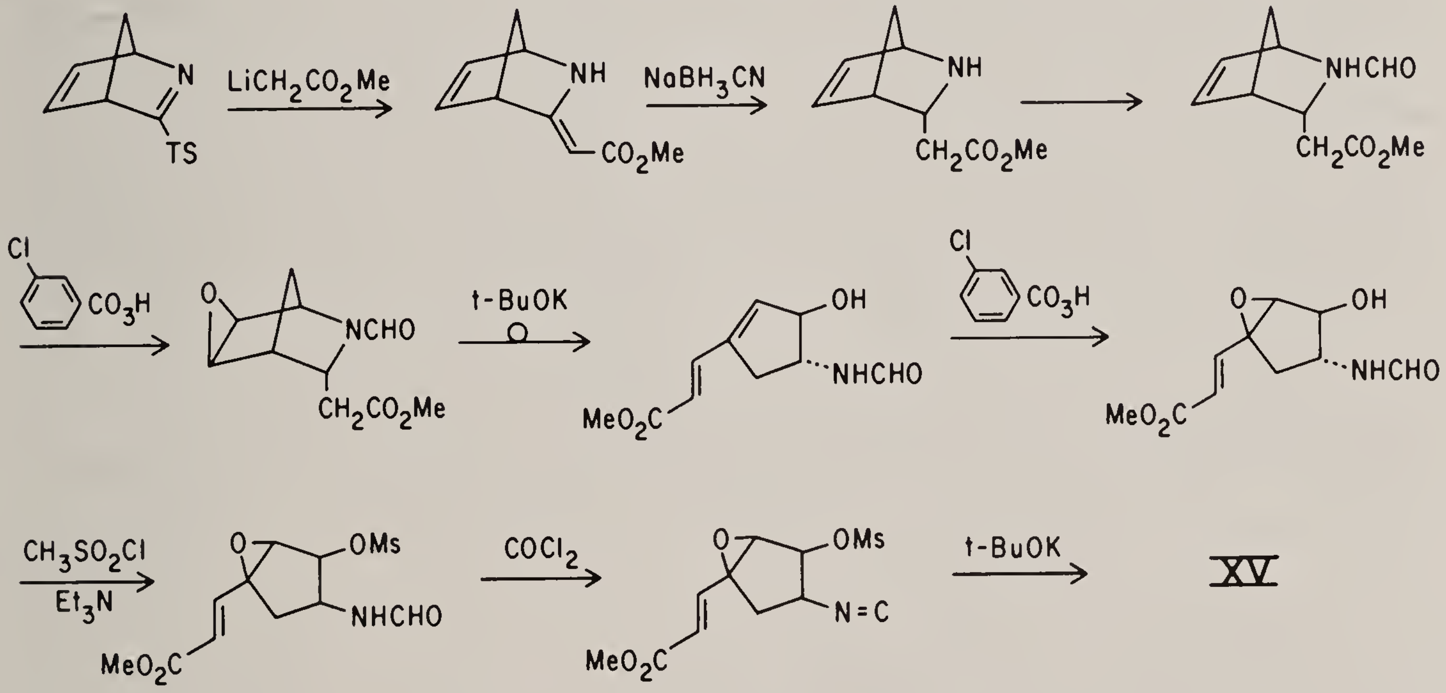
is summarised in scheme 1 and is biosynthetically unique. One particularly interesting feature of the biosynthesis of XVI is the possibility that the exocyclic double bond is isomerised during biosynthesis to the thermodynamically less stable configuration.

Scheme 1



Four of these isocyanides have been synthesised; dermadin (XV, Fukuyama and Yung 1981), XVI (Baldwin *et al.* 1984) XVII and XVIII (Baldwin *et al.* 1985), the first of these being particularly elegant (scheme 2).

Scheme 2

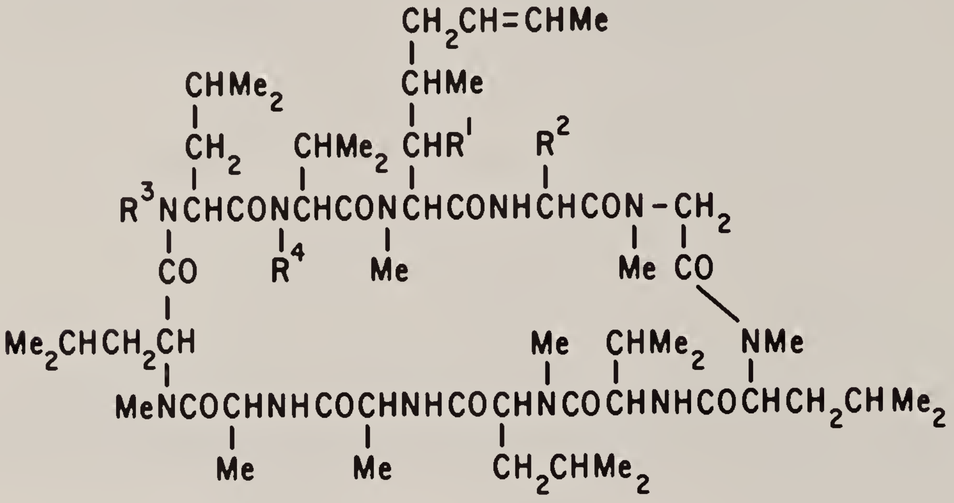


Gliotoxin (XXI) was one of the first fungal metabolites discovered to have antibiotic action (Weindling 1934; Bell *et al.* 1958) and was the first compound demonstrated to have the interesting disulphide bridge across a dioxopiperazine ring (Lowe *et al.* 1966). Interest in the chemistry of this compound has revived recently since it has been shown that it inhibits the immune system of mammals at 50 ng ml^{-1} and organisms capable of producing it have been isolated from the circulatory fluids of patients with the so-called autoimmune deficiency syndrome (Müllbacher and Eichner 1984). Among related compounds is gliovirin (XXV) where the sulphur bridge spans 5 atoms, probably a more stable configuration, analogous to the anisyl thioacetal derivatives used so successfully by Kishi in his synthesis of gliotoxin (Kishi *et al.* 1972). Its only known analogue as a natural product is sporidesmin C (Hodges and

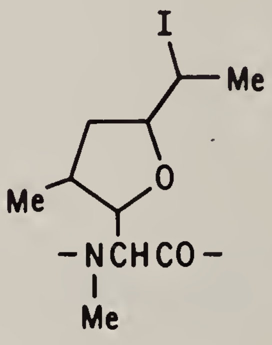
Shannon 1966). The biosynthesis of these sulphur compounds has been exhaustively examined and has been reviewed on numerous occasions (see e.g. Leigh and Taylor 1976).

Polypeptide metabolites other than proteins, of Gliocladium spp., Hypocrea spp. and Trichoderma spp.

The peptide metabolites of these fungi can be divided into two groups - those produced by *Trichoderma polysporum* i.e. XXXIV and XXXVI, and all of the others. This may be a chemotaxonomic basis for the reclassification of *T. polysporum* as *Tolypocladium inflatum* (Traber et *al.* 1982). The structure of the cyclosporins is based

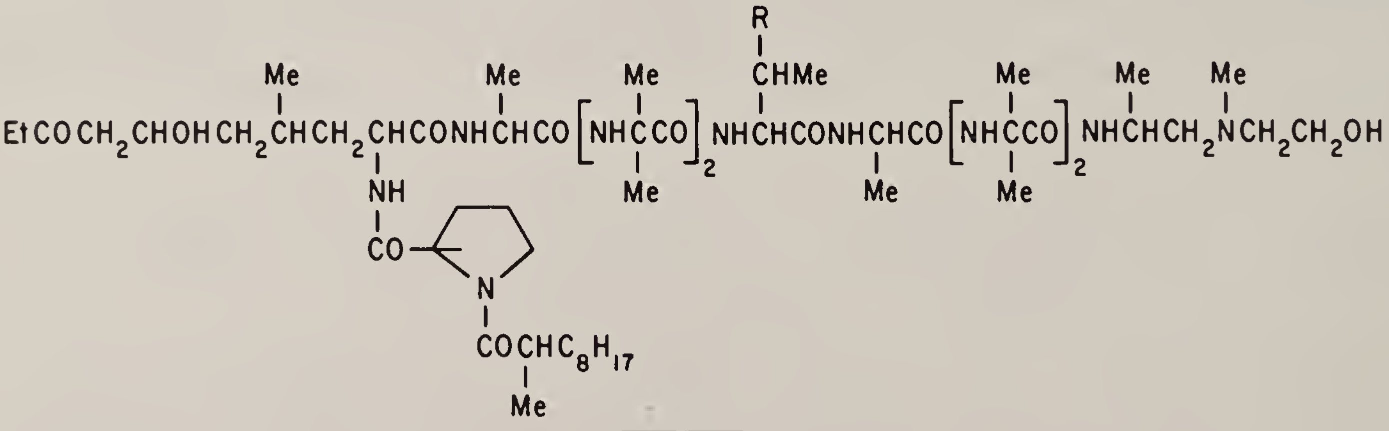


XXXIV

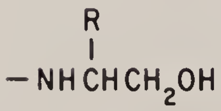


XXXV

on x-ray crystallography of the iodo derivative XXXV in which the 3-hydroxyl group of the unsaturated 4-methylcaprylic acid side-chain and iodine have added to the double bond (Petcher et *al.* 1976). This same hydroxyl group participates in a rearrangement involving the 2-methylamino group of this C_9 amino acid whereby a depsipeptide is produced; the lactone being generated with the proximal valyl residue. No details of the toxicity of such depsipeptides have been revealed. A synthesis of cyclosporin A (XXXIV, R^1-=OH, R^2=Et, R^3=R^4=Me) and its enantiomer cyclosporin H has been reported (Wenger 1984).

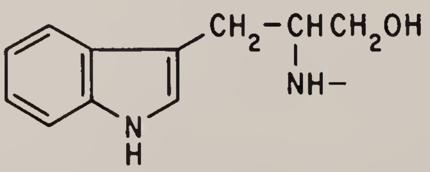


XXXVI

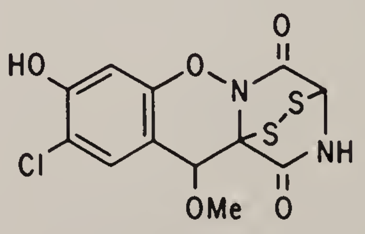


$-\mathrm{NH}\overset{\mathrm{R}}{\mathrm{CH}}\mathrm{CH_2OH}$

XXXVII



XXXVIII



XXXIX

Table V Polypeptide antibiotics produced by *Hypocrea peltata, Gliocladium deliquescens* and *Trichoderma* spp.

Trivial Name	Producing Organism	Structure	m.p.	[α]D	References
Cyclosporin A	T. polysporum	XXXIV, R^1=OH, R^2=Et, R^3=R^4=Me	148-51°	-244°	Ruegger et *al.*, (1976)
Cyclosporin B	- do -	XXXIV, R^1=OH, R^2=R^3=R^4=Me	149-52°	-244°	Traber et *al.*, (1977)
Cyclosporin C	- do -	XXXIV, R^1=OH, R^2=CHOHMe, R^3=R^4=Me	152-5°	-238°	Ruegger et *al.*, (1976)
Cyclosporin D	- do -	XXXIV, R^1=OH, R^2=$CHMe_2$, R^3=R^4=Me	148-51°	-255°	Traber et *al.*, (1977)
Cyclosporin E	- do -	XXXIV, R^1=OH, R^2=Et, R^3=Me, R^4=H	142-3°	-179°	Traber et *al.*, (1982)
Cyclosporin F	- do -	XXXIV, R^1=H, R^2=Et, R^3=R^4=Me	183-4°	-290°	
Cyclosporin G	- do -	XXXIV, R^1=OH, R^2=$CHMe_2$$R^3$=$R^4$=Me	196-7°	-245°	
Cyclosporin H	- do -	XXXIV, R^1=OH, R^2=Et, R^3=R^4=Me	162-5°	-177°	
Cyclosporin I	- do -	XXXIV, R^1=OH, R^2=$CHMe_2$, R^3=H, R^4=Me	137-40°	-177°	
Trichotoxin	T. viride	See Table VI	187°		Hou et *al.*, (1972); Brückner et *al.*, (1979)
Alamethicin	T. hamatum	- do -	275-9°	-5°	Upjohn Co., (1969); Pandey et *al.*, (1977)
Gliodeliquescin	G. deliquescens	- do -	260°		Brückner & Przybylski (1984)
Hypelcin AI	H. Peltata	- do -	265-6°	-17°	Fujita et *al.*, (1979, 1984)
Hypelcin AII	- do -	- do -	254-6°	-1°	
Hypelcin AIII	- do -	- do -	256-8°		
Hypelcin AIV	- do -	- do -	259-61°		
Paracelsin	T. reesei	- do -	253-5°	-19.5°	Brückner et *al.*, (1984)
Suzukacillin	T. viride	- do -	250°	-85.7°	Ooka et *al.*, (1966); Katz (1983)
Trichorzianine	T. harzianum	- do -	253-4°	-25°	Davoust et *al.*, (1983); Bodo et *al.*, (1985)
Trichopolyn I	T. polysporum	XXXVI, R=Et	114-6°		Fuji et *al.*, (1978)
Trichopolyn II = tricholides	- do -	XXXVI, R=Me			Fujita et *al.*, (1981)

Table VI Tentative structures of 2-methylalanine polypeptide antibiotics

Trivial name	Position of amino acid residue from N-terminal end of the chain 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Alamethicin I	Ac	Aib	Pro	Aib	Ala	Aib	Ala	Gln	Aib	Val	Aib	Gly	Leu	Aib	Pro	Val	Aib	Aib	Glu	Gln	P
II							Aib														
Gliodeliquescin			Ala																Gln		
Paracelsin A			Ala										Aib						Gln		
B			Ala							Leu			Aib						Gln		
C			Ala				Aib						Aib						Gln		
D			Ala				Aib			Leu			Aib						Gln		
Suzukacillin I			Ala							Aib									Gln		
II			Ala				Aib			Leu								Iva	Gln		
Hypelcin I							Aib			Leu			Aib						Gln		L
II										Leu			Aib						Gln		L
III							Aib			Leu			Aib						Gln		-
IV							Aib			Ile			Aib						Gln		L
Trichotoxin E			Gly		Leu		O			Aib		Ala	Ala			Leu			O		V
F			Gly		Leu		O			Aib	Ala	Ala	Ala			Leu		Iva	O		V
G			Gly		Leu		O			Aib		Ala	Ala			Leu			O		V
Trichorzianine AIIc			Ala	0			Aib			Aib		Ser						Ile	Gln		T

Abbreviations: Aib = 2-methylalanine; Iva = 2-ethylalanine; P = XXXVII, R=$CH_2C_6H_5$; L = XXXVII, R=CH_2CHMe_2; V = XXXVII, R = $CHMe_2$; T = XXXVIII; O = residue missing; - = unkno[illegible] Ac = CH_3CO-. All other amino acid abbreviations are standard. A blank indicates the amino acid cited at the top of the column.

By contrast, the structures of the remaining metabolites summarised in Tables V and VI are less secure. All of the compounds given in the Tables are in fact complex mixtures analogous to the cyclosporins (Brewer *et al.* 1979, Shaw and Taylor 1986). In the case of alamethicin, x-ray crystallography of the mixture of metabolites (Fox and Richards 1982) has provided impressive support of the structure proposed by Pandey *et al.* 1977) based on degradative chemistry and mass spectroscopy. The data given in Table VI reveals that about 10 i.e. half of the positions in the chain are invariate and only at position 10 are there more than 2 or 3 variations. Such variations are common in other congeneric peptide metabolites (Taylor 1970) especially if the known relationship of valine with 2-methylalanine (Ooka and Takeda 1974) is taken into account. There have been 4 totally independent attempts to synthesise the proposed alamethicin sequence (Nagaraj and Balaram 1981a, Gisin *et al.* 1981, Balasubramanian *et al.* 1981, Schmitt and Jung 1985). The results of this prodigious effort have been summarised by the latter authors, whose synthesis uniquely considered the stereochemical complexities of the procedure. All four products had different physical properties, only two were reported to have biological activity - if the detergent properties of all such lipophilic peptides are not considered. It must be emphasised that these discrepancies indicate non-trivial chemical problems associated with the determination of purity and hence identity of such large molecules. The composition and proportions of peptide metabolites is greatly influenced by the fermentation conditions (Brewer *et al.* 1979) and it is therefore possible that many of the assemblies of congeners given in Tables V and VI contain identical components. However, a test of this supposition will require much better methods of separation than those currently available.

A number of other peptide metabolites of this group of fungi have been reported but at present have not been characterised to the same extent as those in Table V. These include antibiotic 1037 ($[\alpha]_D$-8°, Ooka 1977) produced by *T. viride* and a phytotoxic substance 11313 (m. p. 330-1°) produced by *Gliocladium zaleskii* (Nazarova and Zakharova 1982).

Biosynthetic studies have been made in the cases of alamethicin and suzukacillin. Good evidence that the biosynthesis was not ribosomal, but analogous to that of valinomycin or gramicidin A was obtained by Reusser (1966), and much later by Kleinkauf and Rindfleisch (1975). It has been proposed that the biosynthesis starts at the N-acetyl 2-methylalanyl N-terminal moiety and thence proceeds stepwise by addition of amino acid residues as activated thio esters (Mohr and Kleinkauf 1978). The mechanism of chain termination with a β-amino alcohol is unknown but the latter authors have provided some information about the generation of this C-terminal residue.

Toxicity of metabolites of Gliocladium spp., Hypocrea spp., and Trichoderma spp.

No attempt is made in this section to give a complete account of all the toxicological studies to be found in the literature on the compounds described in Tables II-V. Table VII is an attempt to reduce this literature, drastically, so that comparisons can be made. In general organisms have been selected to appear in Table VII because they are commonly used in toxicological studies, and to some extent comparisons are permissable. However, many toxicological phenomena cannot be conveniently tabulated and these matters are presented in the following text where each group of metabolites (as in Tables II-V) is discussed in turn. Problems of synergy are appreciated but not considered.

Polyketide metabolites (Table II) Very little is known of the toxicological properties of benzoquinones such as aurantiogliocladin (I, R=Me, R′=R″=OMe). Of course benzoquinone is known to be irritant and the recommended safety level of its vapour is about 0.1 p.p.m. (Sax 1968). The m. p. of benzoquinone is 115° and it is therefore

Table VII Toxicities of metabolites of *Hypocrea* spp., *Gliocladium* spp., and *Trichoderma* spp.

Metabolite	Structure	Toxicity In vitro antimicrobial activity (μg ml^{-1}) Antibact. Gram+	Gram-	Antifung.	Growth of mammalian cells μg ml^{-1}	LD$_{50}$ in Mammals. Route of Admin. (mg kg^{-1})		References
Aurantiogliocladin	I, R=Me, R′=R″=OMe	200^{a}	400^{b}	50^{A}				Brian *et al.*, (1951)
Glioresein	I, dihydro, R=Me R′=R″=OMe	200^{a}	400^{b}	400^{A}				- do -
Dehydroacetic acid	XXX	3000^{g}	2000^{h}	500^{E}		oral	1000^{R}	Spencer *et al.*, (1950)
Gliocladic acid	V				active	oral	200^{M}	Itoh *et al.*, (1982)
Heptelidic acid	VI	25^{c}	0.4^{D}		0.25	i.p.	31.5^{M}	Itoh *et al.*, (1980)
Trichodermin	IX, R=R‴=H, R′=Me, R″=OAc			$+^{B}$		s.c.	500^{M}	Yamamoto *et al.*, (1969)
T_2-toxin	IX, R=OCOCH$_2$CHMe$_2$, R′=CH$_2$OAc, R″=OAc, R‴=OH			30^{E}	0.03	oral	4^{M}	Ueno *et al.*, (1973); Marasas *et al.*, (1969); Schappert and Khachatourians (1983)
Viridin	X, Y=O			0.006^{A}				Brian *et al.*, (1946)
Isonitrin D	XI	200^{a}	200^{b}	12.5^{B}				Fujiwara *et al.*, (1982)
Isonitrin B	XII	200^{a}	100^{b}	200^{B}		i.p.	300^{M}	- do -
Isonitrin A	XIII	12.5^{a}	1.56^{b}	6.25^{B}		i.p.	160^{M}	- do -
Trichoviridin	XIV	100^{a}	6.26^{b}	25^{B}		i.p.	100^{M}	- do -
Dermadin	XV	2.3^{e}	3.13^{b}	200^{B}		i.p.	240^{M}	- do - Brewer *et al.*, (1982)
	XVI	2.5^{e}	1.5^{f}	200^{B}		i.p.	20^{M}	Fujiwara *et al.*, (1982)
Gliotoxin	XXI	0.8^{a}	18.7^{b}	100^{B}	0.1	oral	50^{M}	Brewer *et al.*, (1966)
						i.p.	50^{M}	Taylor (1971); Allen *et al.*, (1954); Johnson *et al.*, (1943)

Gliovirin	XXV			0.06^{C}				Howell and Stipanovic (1983)
Trichorin A			50*					Katayama *et al.*, (1977)
Cyclosporin A	XXXIV, $R'=OH$, $R^2=Et$, $R^3=R^4=Me$			3^{D}	4	oral	2000^{M}	Traber *et al.*, (1977); Gorden and Singer (1979); Borel *et al.*, (1976)
Cyclosporin B	XXXIV, $R^1=OH$, $R^2=R^3=R^4=Me$			3^{D}				- do -
Cyclosporin C	XXXIV, $R^1=OH$, $R^3=Me$, $R^4=Me$, $R^2=CHOHMe$			1^{D}				- do -
Cyclosporin D	XXXIV, $R^1=OH$, $R^3=Me$, $R^4=Me$, $R^2=CHMe_2$			1^{D}				- do -
Alamethicin	See Table VI	31^{c}	200^{i}	100^{F}		oral	80^{M}	Meyer and Reusser (1967); Brewer *et al.*, (1979)
Hypelcins	- do -	25^{a}	100^{b}	100^{G}				Fujita *et al.*, (1984b)
Paracelsins	- do -					i.p.	5^{M}	Brückner *et al.*, (1984)
Suzukacillin	- do -	10^{a}		100^{D}				Ooka *et al.*, (1966)
Trichotoxin	- do -	1000^{g}				i.p.	4.36^{M}	Hou *et al.*, (1972)
						oral	600^{M}	- do -
Trichorzianine	- do -		$+^{H}$					Merlier *et al.*, (1985)
Trichopolyns	XXXVI	6.25^{a}	100^{b}	6.25^{B}		i.p.	5^{M}	Fuji *et al.*, (1978)

Abbreviations: Bacteria: a=Bacillus subtilis, b=Escherichia coli, c=Streptococcus faecalis, d=Bacterioides fragilis, e=Micrococcus luteus, f=Bacterioides succinogenes, g=Staphylococcus aureus, h=Salmonella typhosa, i=Selenomonas ruminantium. Fungi: A=Botrytis allii, B=Candida albicans, C=Pythium ultimum, D=Aspergillus niger, E=Saccharomyces cerevisiae, F=Blastomyces dermatitidus, G=Trichophyton rubrum, H=Botrytis cinerea. Animals: M=Mice, R=rats. *=organism not given; +=concentration unknown.

possible that the more volatile benzoquinone metabolites (I, m. p. 63°, Table 2) could achieve high concentrations in enclosed spaces should building structural material become colonised with isolates of *Gliocladium roseum* capable of their production. The orcinol derivatives (Pettersson 1965) are probably much less toxic since the LD_{50} of orcinol in mice is known to be 722 mg kg^{-1} (Veldre *et al.*, 1971). The anthraquinones (XXXII) are generally regarded as non-toxic though emodin (XXXII, $R=R^1=R^3=OH$, $R^2=Me$) is thought to be one of the active ingredients in traditional purgatives.

The pyrone derivatives (IV, $x=CH_2$-CH_2, CH=CH) were first isolated during investigations of the odors associated with these fungi e.g. in brackish water (Kikuchi *et al.* 1974) and in the latter case to find the agent capable of initiating oospore formation in *Phytophthora*. However there has been a recent claim (Merlier *et al.* 1985) that the C_5H_{11} pyrone is fungicidal. Dehydroacetic acid (XXX) has some claim as a general antiseptic in view of its bactericidal action (Spencer *et al.* 1950) and low toxicity, but it has not been used because of the superior properties of detergents such as cetyl trimethylammonium halide.

Terpene metabolites (Table III) Avellaneol (III) has been reported (Nair *et al.* 1982) to be active against PS 388 lymphocytic leukemia in mice, but no experimental details were given.

Gliocladic acid (V) and heptelidic acid (VI) were discovered during investigations of the biological activity of a number of isolates of *Gliocladium virens, Trichoderma viride*, and *Chaetomium globosum* from soil. Gliocladic acid at a dose of 3 mg kg^{-1} in female mice inhibited the growth of sarcoma-37 by 46% and was less toxic than the related metabolite heptelidic acid (Itoh *et al.* 1982). The latter acid has a noticeable specificity for inhibition of growth of some anaerobic bacteria though the range of bacteria that are susceptible is narrower than that affected by the isocyanide XVI.

Trichodermin (IX, R=R‴=H, R′=Me, R″=OAc) and T_2-toxin (IX, $R=OCOCH_2CHMe_2$, $R'=CH_2OAc$, R″=OH) represent the extremes of toxicity found in more than 100 trichothecins now known to be produced by fungi. In all cases that have been examined in detail large numbers of congeneric trichothecins have been found (e.g. Greenhalgh *et al.* 1984), and it therefore seems likely that the *Trichoderma* spp. that have been reported to produce trichodermin and T_2-toxin also produce a range of trichothecins in low concentration. It can be seen from Table VII that there are more than two orders of magnitude in the acute toxicity of trichoderm and T_2-toxin in mice. Thus the precise toxicity of the mixture of metabolites produced by a particular isolate will depend on the toxicity *of the mixture*. The factors that govern the composition of such mixtures are unknown. The literature devoted to the toxicity of T_2-toxin is very large (for a general review see Ueno 1983) since it has been implicated in mycotoxicoses in farm animals (Mirocha 1983) and in alimentary toxic aleukia in man (Joffe 1974). In general trichothecins have little or no antibacterial properties, but inhibit the growth of fungi and other eukaryotic cells. Thus rapidly growing cells such as B and T lymphocytes are particularly susceptible and there is a growing literature on the effect of T_2-toxin on the mammalian immune system. The reader is referred to one of the reviews cited above for further details on the toxicology of this and other trichothecins.

Viridin (X, Y=0) and viridiol (X, Y=H, OH) are unusual steroid derivatives that are very active inhibitors of fungal spore germination (Brian *et al.* 1946). The germination of spores of *Collectotrichium lini* and *Fusarium coeruleum* was inhibited at 3 ng ml^{-1} and the germination of spores of *Cladosporium herbarum, Fusarium culmorum, Penicillium digitatum, P. notatum*, and *Stemphyilium* spp. at 0.2 $\mu g\ ml^{-1}$. Viridin was only fungicidal to the latter fungus at 50 $\mu g\ ml^{-1}$. No data on the mammalian toxicity of viridin has been published.

Non-polypeptide metabolites derived from α-amino acids

From a toxiciological point of view these metabolites fall into two groups - the cyclopentenylisocyanides and the epidithiodioxopiperazines.

CycloPentenylisocyanides. The first report of these compounds as metabolites occurred about 8 years ago (Nobuhara *et al.* 1976) and work on their toxicity has been hampered by their instability. However in the period that has elapsed since 1976 they have emerged as very common metabolites of *Trichoderma hamatum* (Brewer and Taylor 1981) and several other *Trichoderma* spp. (Fujiwara *et al.* 1982). They have marked bacteriostatic properties but the bacterial spectrum that is susceptible is unusual. The growth of Gram + bacteria except for *Sarcina lutea* is inhibited at concentrations greater than 100 μg ml^{-1}, but Gram - bacteria and particularly obligately anaerobic bacteria are inhibited in the concentration range 0.1-10 μg ml^{-1}. Bacteria that digest cellulose are very susceptible, especially to the unstable compound XVI. Thus cellulose digestion is inhibited by XVI in *Ruminococcus albus* at 5 μg ml^{-1}; in *R. flavofasciens* at 6 μg ml^{-1} and in *Bacterioides succinogenes* at 1-2 μg ml^{-1} (Liss *et al.* 1985). In general the genus *Bacterioides* is very susceptible to this antibiotic. At minimum inhibitory concentrations of XVI its activity is reversed by addition of approximately equimolar amounts of nickelous ion (Brewer *et al.* 1986) and it has been suggested that the mode of action of these compounds lies in their ability to co-ordinate with Ni cofactors (Whitman and Wolfe 1980) implicated in, for example, the reduction of pyruvate to propionate or formaldehyde to methane. The acute toxicities of these isocyanides to mice is given in Table VII (Fujiwara *et al.* 1982) and it can be seen that the toxicities of the various compounds very considerably. One of the most toxic, XVI, has been fed to lambs, intraruminally at a dose level of 5 mg kg^{-1} day^{-1} for 3 weeks without overt toxicity, apart from a slightly slower weight gain which could be attributed to an induced, reduced digestibility of the feed.

Epidithiodioxopiperazines. The toxicity of gliotoxin (XXI) has been known for more than 50 years, but early reports of its fungicidal activity were probably biased by the contamination of specimens with viridin. However Johnson *et al.* (1943) showed that gliotoxin was bacteriostatic at about 0.5 μg ml^{-1} against Gram + bacteria and at about 10 μg ml^{-1} against Gram - organisms. It inhibited the growth of *Penicillium italicum* at 100 μg ml^{-1}, *Rhizopus* sp. at 10 μg ml^{-1} and *Aspergillus niger* at 1 μg ml^{-1}. Its LD$_{50}$ in mice, rats and rabbits was about 50 mg kg^{-1}, whether dosed orally, intraperitoneally, or intravenously. Two developments in its toxicology have occurred since this work was published. The first was the discovery that gliotoxin inhibited the growth of RNA virus in cell culture (Rightsel *et al.* 1964; Miller *et al.* 1968). A comprehensive review of its toxicology prior to 1970 has been published (Taylor 1971). The latest event is the report that gliotoxin inhibits phagocytosis of macrophage at 20-50 ng ml^{-1} and that at 0.1 μg ml^{-1} it abrogates induction of alloreactive cytotoxic T lymphocytes (Müllbacher and Eichner 1984). Since *Aspergillus fumigatus* is not only a known human pathogen but it is also known to produce gliotoxin (Menzel *et al.* 1944), there arises the question of whether the toxin is produced *in vivo*, and if so what effect this may have on the progress of an infectious agent(s). Gliovirin (Stipanovic and Howell 1982) which seems to be very similar to trichorin (Katayama *et al.* 1977) has a growth inhibiting effect on a very narrow range of fungi, though trichorin is known to have some effect on the growth of (unspecified) Gram - bacteria. The structure of gliovirin has some similarity to that of A30641 (XXXIX, though this structure has been questioned, Sakata *et al.* 1982), which has marked antifungal activity (Berg *et al.* 1976).

Non-protein polypeptide metabolites These compounds (Tables V and VI) fall into two groups - the cyclosporins, and linear peptides that contain several 2-methylalanine residues.

Cyclosporins. About 9 of these metabolites have been characterised but cyclosporin A (XXXIV, R^1=OH, R^2=Et, R^3=R^4=Me) has been the main subject of toxicity studies.

These compounds have little or no bacteriostatic effect but as shown in Table VIII both cyclosporin A and cyclosporin C (XXXIV, R^1=OH, R^2=CHOHMe, R^3=R^4=Me) inhibit the growth of fungi and in some cases at low concentration (Dreyfuss et *al.* 1976); this activity perhaps provides a rationale for the use of these compounds in the treatment of patients with immune deficiency. However the main toxicological properties of these compounds are their remarkable effects on the immune system of mammals. The literature on this subject is large and growing. Some indication of its size may be had from the facts that there are 149 references to this subject in the 10th collective index of Chemical Abstracts, but 70 references in the 6 month period (Vol. 101) July-December 1984. No attempt to review this literature is made - the reader can consult several excellent surveys e.g. Weil 1984, Thomson et *al.* (1984). Renal and/or hepatic and/or hemopoietic abnoramlities have been found in mice, rats, rabbits, dogs, chickens and monkeys at dose levels of about 25 mg kg^{-1} day^{-1}. In man this is about twice the dose used in immunosuppressent therapy. It may be concluded that the low concentrations of these compounds possibly present in the environment are not a toxicological hazard.

Table VIII Growth inhibition of some fungi by cyclosporin A and cyclosporin C

Organism inhibited	Minimum Inhibitory Concentration (μg ml^{-1}) Cyclosporin A	Cyclosporin C
Rhodotorula rubra	100	100
Oospora lactis	31.6	100
Aspergillus niger	3	1
Curvularia lunata	1	1
Neurospora crassa	10	10
Anixiopsis stercoraria	100	100
Trichophyton quinckeanum	10	31.6

Alamethicin-like peptides. These compounds inhibit the growth of a wide range of bacteria and fungi. Representative examples are given in Table VII. It is possible that some of the discrepancies in the literature regarding the bacteriostatic effect of these metabolites is due to the fact that they diffuse slowly through agar. Thus the diameter of zones of inhibition depend, more critically than usual, on the time of diffusion before inoculation. In general the LD_{50} in mice treated intraperitoneally with any of these compounds is about 5 mg kg^{-1}, but about 100 times this dose can be tolerated when it is administered orally. This also is probably due to slow diffusion and hence uptake through the wall of the gut. Paradoxically, the great interest that these compounds have evoked lies in their remarkable effects on membrane physiology. This subject has stimulated a great deal of interest and there are several excellent reviews available on the subject (e.g. Jung et *al.* 1979, Nagaraj and Balaram 1981b). In brief, these are amphiphilic molecules which differ from such trans-membrane carriers as valinomycin (where transport is dependent on the selective residence of a metal ion e.g. K^+ in the interannular space of the cyclic peptide) or gramicidin A (which induces a voltage independent dimeric channel) by inducing conductance which is exponentially dependent on the applied voltage. The channel structures (Fox and Richards 1982) are characterised by an hydrophilic interior and a hydrophobic exterior and are stabilised by an hydrated annulus of glutamine residues. A model for the mechanism of pore formation has been proposed by Jung and his coworkers (Boheim et *al.* 1983). Thus the mammalian toxicity of the metabolites is probably manifested by their effect on neuro-transmission, though their access to such sensitive receptors is limited by their high molecular weight. In general they are not hydrolysed by peptidases and thus might progress through the gut unscathed, affecting the intestinal flora in a possibly deleterious way.

Miscellaneous antagonistic effects of Trichoderma spp. Mycologists have been interested in the phenomenon of soil fungistasis for more than 50 years and the suspicion that *Trichoderma* spp. were involved has been entertained by many workers (see e.g. Elad *et al.* 1980, Widden and Abitol 1980). Unambiguous experimental evidence for the phenomenon is however rare - Mitchell and Dix (1975) showed that the germination of *Trichoderma* spores was inhibited by sterile soil but by contrast Lewis and Papavizas (1984) found that *Trichoderma* spp. proliferated in soil when added as a mycelial culture. Dennis and Webster (1971b) have shown, by elegant photomicroscopy, that *Trichoderma* spp. can grow on the mycelium of other fungi and in the Soviet Union (Kanivets *et al.* 1940) increased yields of several crops have been claimed after infestation of soil with *Trichoderma lignorum*. Earlier work on the role of gliotoxin in soil fungistasis has been reviewed (Taylor 1971). In summary the use of *Trichoderma* spp. as agents in biocontrol systems has stimulated much work but little practical application has as yet emerged.

Methods and agents for the control of growth of Trichoderma and taxonomically related genera

A representative selection of compounds that have been claimed to retard the growth of these fungi is given in Table IX. The bulk of these compounds fall into the categories: fungicidal triazines (XL), benzimidazoles (XLI, see in addition Tabata and Kondo 1977), phenylurea/urethanes (XLIII, XLIV), thiourea/thiourethanes (XLVIII, LII) and insecticidal chlorinated hydrocarbons (XLV, XLVI, LIII). The number of compounds studied in each group is probably large but details of the concentrations at which inhibition was observed are hard to find. For example, among chlorinated compounds patent protection for compounds of the type $ROCH_2CH{=}CHCH_2Cl$ ($R{=}Me$, C_6H_5, Cass 1949) was obtained as antagonists of *Gliocladium fimbriatum* but there seems to have been no exploitation of this discovery. Similarly considerable work has been done on the effect of dichlorvos ($(MeO)_2POOCH{=}CCl_2$) on *Trichoderma viride* (Matsumora and Boush 1968) but I have been unable to find the minimum concentration of this insecticide that inhibits growth of the fungus. It seems to be generally held that chlorophenols preserve wood from all but superficial attack by these fungi (Lew and Wilcox 1981, Cserjesi and Rolf 1976) but I have been unable to find details of the relationship between structure and activity despite the known mammalian toxicity of these compounds (Sax 1968).

The importance of the preservation of wood has led to many studies of the antifungal effects of fumigation. Reference has already been made to the disastrous use of formaldehyde for this purpose; ethyl mercaptan has also been used (Kvasnikov *et al.* 1971) but had no effect on *Gliocladium salmonicolor* and only slight effect (at 0.6 $\mu g\ ml^{-1}$) on *Trichoderma lignorum*.

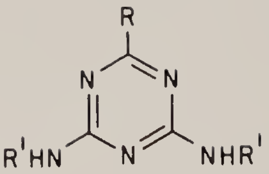
There remain a miscellaneous group of materials that have growth suppressive activity, at relatively high concentration; these include: manganous ion (at 0.5 mg ml^{-1}, Babich and Stotzky 1981), certain alkyloxyacetic acids ($ROCH_2CO_2H$, $R{=}C_8H_{17}$, C_9H_{19}, $C_{11}H_{23}$; 0.1 mg ml^{-1}, Gershon *et al.* 1979), a tetraene antibiotic (Chakrabarty and Chandra 1979), and certain α-naphthoquinones (0.1 mg ml^{-1}, Tripathi *et al.* 1980).

A further group of poorly defined materials include bacterial volatile metabolites (Moore-Landecker and Stotzky 1972) and hot water extracts of oak-bark - probably tannic acids and catechin (LIV, Yoshimoto *et al.* 1984). Finally there are reports of suppression of spore germination of *Trichoderma viride* by ozone (Hibben and Stotzky 1969); actinomycin D (0.1 mg ml^{-1}); cycloheximide (0.005 mg ml^{-1}) and 5-fluorouracil (0.01 mg ml^{-1}, Betina and Spisiakova 1976).

Table IX Compounds known to inhibit growth of *Hypocrea pilulifera*, *Gliocladium* spp. (G), and *Trichoderma* spp. (T)

Trivial Name of Inhibitor	Chemical Structure	Susceptible Fungi	Min. Growth Inhib. Conc. ($mg\ ml^{-1}$)	References
Atrazine	XL, R=Cl, R′=Et, R′=$CHMe_2$	T		Couch *et al.*, (1965)
			0.1	Stratton (1983)
Benomyl	XLI, R=$CONHC_4H_9$, R′=$NHCO_2Me$	G		Davet (1980)
		T. viride		- do -
		T. harzianum		Davet (1981)
		- do -		Cserjesi and Rolf (1976)
		T. virgatum		- do -
Benlate	- do -	T		Usui and Iida (1980)
Thiuram	LII	T		- do -
		T	0.3	Popescu (1979)
Butachlor	XLII, R′=Et, R^2=$COCH_2Cl$, R^3=$CH_2OC_4H_9$, R^4=H	T		Chen (1980)
Carbendazim	XL, R=H, R′=$NHCO_2Me$	G		Davet (1980)
		T. viride		- do -
2,4-Damine	?XLII, R′=R^4=Cl, R′=R^2=H, R^3=CH_2CO_2H	- do -	1	Pommer (1966)
Dalapon	2,2-dichloropropionic acid	- do -		Senior *et al.*, (1976)
DDT	XLV	- do -	0.03	Singh *et al.*, (1977)
	Dipropyleneglycol dibenzoate	T. longibrachiatum		Butz *et al.*, (1983)
Diuron	XLIII, R^1=R^2=Me, R^3=R^4=Cl	T. viride	10	Davis *et al.*, (1976)
Endrin	XLVI	- do -		Singh *et al.*, (1977)
		T		Patil *et al.*, (1970)

EPTL	$(C_3H_7)_2NCOSEt$	T. viride		Peeples (1972)
Fluometuron	XLIII, $R^1=R^2=Me$, $R^3=H$, $R^4=CF_3$	- do -	10	Davis et *al.*, (1976)
Heptachlor	LIII	- do -	0.01	Singh et *al.*, (1977)
	Hexachlorobutadiene	T. lignorum	1-10	Mukasheva (1976)
		G. verticilloides	1-10	- do -
Lindane	Benzene hexachloride	T. viride	0.03	Singh et *al.*, (1977)
Linuron	XLIII, $R^1=Me$, $R^2=OMe$, $R^3=R^4=Cl$	- do -		Glad et *al.*, (1981)
Methabenzthiazuron	XLVII	Hypocrea pilulifera	.059	Göttfert and Corte (1978)
Methylthiophanate	XLVII	T. viride		Davet (1980)
		G		- do -
Mexacarbate	XLII, $R^1=R^2=R^3=Me$, $R^4=CO_2NHMe$	T. viride	0.008	Benezet and Matsumura (1974)
MSMA	Monosodium methanarsenate	- do -	10	Davis et *al.*, (1976)
Phenmediphan	XLIV, R=Me	- do -		Bellinck (1980)
	XLIV, R=H	- do -		- do -
	XLII, $R^1=R^2=H$, $R^3=CO_2Me$, $R_4=OH$	- do -		- do -
Permethrin	XLIX	- do -	0.1	Stratton (1983)
	Phenyl mercuric acetate	T	0.1	Popescu (1979)
Prometryn	XL, R=SMe, $R'=CHMe_2$	T. viride	1	Davis et *al.*, (1976)
Sicarol	L	T		Anilkumar and Sastry (1979)
Simazine	XL, R=Cl, R′=Et	T		Couch et *al.*, (1965)
Solanine	LI	T. viride	2	Patil et *al.*, (1972)
Thiabendazole	XLI, R=H, R′=2-thiazolyl	T. harzianum		Cserjesi and Rolf (1976)
		T. virgatum		- do -
	Bu_3SnR (R=Cl, O, OAc)	T. viride		Selivokhin et *al.*, (1974)
Trifluorin	XLII, $R^1=NO_2$, $R^2=R^3=C_3H_7$, $R^4=CF_3$	T. viride		Zayed et *al.*, (1983)
Topsin M	XLVIII	T. lignorum	0.01-	Zoltanska (1984)
		T. koningii	0.001	- do -
		T. album	- do -	- do -



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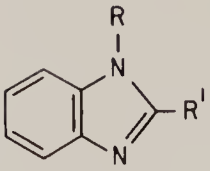

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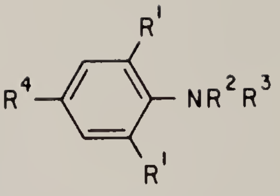

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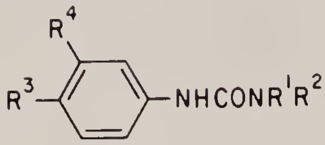

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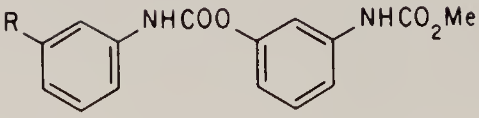

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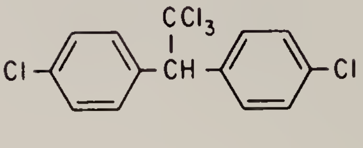

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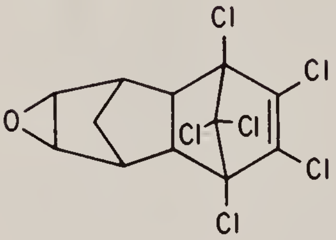

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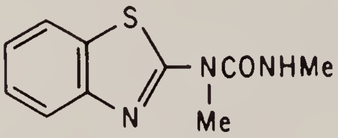

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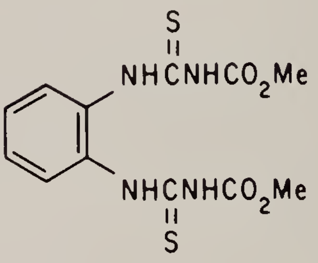

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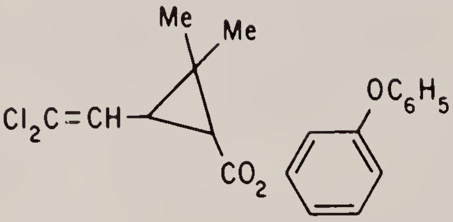

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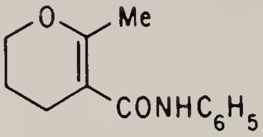

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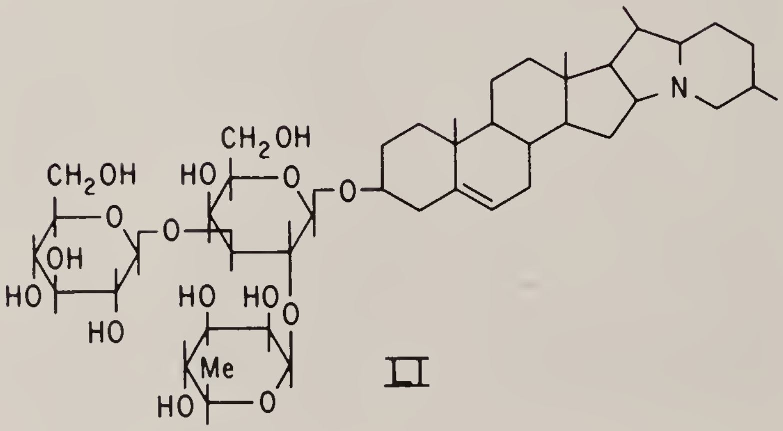
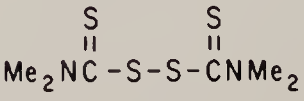
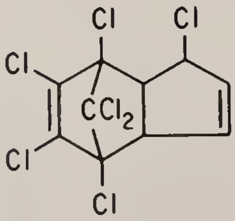


LI

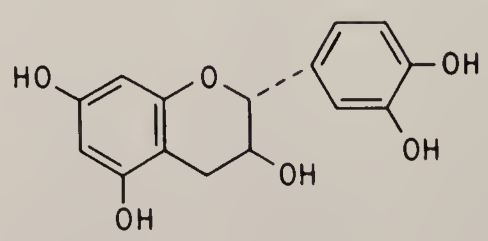


$$\mathrm{Me_2N\overset{S}{\overset{\|}{C}}-S-S-\overset{S}{\overset{\|}{C}}NMe_2}$$

LII



LIII



LIV

Conclusions

The data in the tables of this report demonstrate that the group of fungi that is its subject can be found in almost any environment of the planet; that they produce well-defined metabolites whose biological and chemical properties differ, but which include some of the most toxic substances hitherto described. Only under exceptional circumstances, e.g. when volatile metabolites accumulate in an enclosed space, when metabolites are produced in the course of an infectious process or when they are concentrated naturally in or during the manufacture of food, are acute, toxic manifestations patent. Such toxicity is rare, though an increasing number of examples are coming to light because of the use of better analytical facilities. In the case of long-term sub-clinical toxicity it is usually very difficult to associate cause and effect and therefore epidemiological phenomena of this sort are commonly overlooked. An appreciation of the latter problem and its implications for public heatlh is long overdue, but our ability to assess the importance of such chronic toxicities in society is hampered by inadequate analytical tools.

Until such methods become available our only recourse is to start with the population dynamics of this group of fungi making the assumption that the population density is related in some unknown way with the presence, composition, and concentration of its toxic metabolites. However this job can hardly be started because the taxonomy of this group (and related groups) of fungi fails to provide easy identification and hence classification. Assuming (as seems likely) that these problems can be solved there remains the question of the selective inhibition of fungal growth. Here the prognosis is not bright, because their elimination is probably undesirable, since there are those who believe them to be useful vectors in biological control methods, and perhaps more cogently, that elimination of a relatively benign component of the flora might result in its replacement with a virulent pathogen. Thus fungistatic agents are required, hopefully active at very low concentrations. The antifungal agents summarised in Table IX are effective at concentrations that are at least 4 orders of magnitude greater than e.g. the concentration of penicillin that inhibits the growth of *Streptococcus* spp. It can therefore be concluded that a considerable research effort is required to find antifungal agents that are effective in the concentration range 0.01 - 1 $\mu g\ ml^{-1}$. An examination of the dates of publications cited in Table IX indicates that the large economic losses due to fungal infestation of wood, wood products and cellulosic materials are in fact stimulating such a research programme, and on a world-wide scale. One hopes that the public health aspects of sub-acute mycotoxicoses, together with the growing realisation of their importance in animal production will provide further impetus for this research.

References

Abramova, E.A., Kanevskaya, I.G. and **Bufetchikova, O. Yu.** 1973. Effect of the degree of fungal damage on the properties of partially acetylated cellulose hydrate fibers. *Zh. Prikl. Khim,* 46: 1387-9.

Achilladelis, B.A., Adams, P.M. and **Hanson, J.R.** 1972. Studies in terpenoid biosynthesis. Part VIII. The formation of the trichothecane nucleus. *J. Chem. Soc.* (Perkin Trans. I). 1425-1428.

Adams, P.M. and **Hanson, J.R.** 1972. Sesquiterpenoid metabolites of *Trichoderma polysporum* and *T. sporulosum. Phytochemistry,* 11: 423.

Aguirre, F., Maldonado, O., Rolz, C., Menchu, J.F., Espinosa, R. and **de Cabrera, S.** 1976. Protein from waste. Growing fungi on coffee waste. *Chem. Abs.,* 85: 190592.

Allen, R.E., Shelton, R.S. and **Van Campen, M.G.** 1954. Antifungal agents. Some 3-imino-5-alkylmercapto-1,2,4-dithiazole salts. *J. Amer. Chem. Soc.,* 76: 1158-9.

Ananthasubramanian, L., Carey, S.T. and **Nair, M.S.R.** 1978. Metabolites of pyrenomycetes IX. Structure and absolute configuration of (+)-R-avellaneol, an antibiotic metabolite of Hypocrea avellanea. *Tet. Let.,* 3527-8.

Anilkumar, T.B. and **Sastry, M.N.L.** 1979. Effect of sicarol on the growth of Trichoderma sp. *Chem. Abs.,* 91: 118463.

Anisimov, A.A., Smirov, V.F., Semicheva, A.S. and **Sheveleva, A.F.** 1977. Protection of KD-type epoxy compounds from the effect of biological corrosion by introducing fungicidal additives into their compositions. *Chem. Abs.*, 87: 79467.

Arigioni, D., Cane, D.E., Müller, B. and **Tamm, C.** 1973. The mode of incorporation of farnesyl pyrophosphate into verrucarol. *Helv. Chim. Acta*, 56: 2946-9.

Babich, H. and **Stotzky, G.** 1981. Manganese toxicity to fungi: influence of pH. *Bull. Environ. Contam. Toxicol.*, 27: 474-480.

Balasubramanian, T.M., Kendrick, N.C.E., Taylor, M., Marshall, G.R., Hall, J.E., Vodyanoy, I. and **Reusser, F.** 1981. Synthesis and characterization of the major component of alamethicin. *J. Amer. Chem. Soc.*, 103: 6127-32.

Baldwin, J.E., Adlington, R.M. and **Chondrogianni, J., Edenborough, M.S., Keeping, J.W.** and **Ziegler, C.B.** 1985. Structure and synthesis of new cyclopentenyl isonitriles from *Trichoderma hamatum* (Bon.) Bain. aggr. HLX 1379. *J. Chem. Soc., Chem. Commun.*, 816-817.

Baldwin, J.E., Kelly, D.R. and **Ziegler, C.B.** 1984. The synthesis of a fungal isonitrile antibiotic via a novel radical addition-elimination reaction. *J. Chem. Soc., Chem. Commun.*, 133-134.

Bamburg, J.R. and **Strong, F.M.** 1969. Mycotoxins of the trichothecane family produced by *Fusarium tricinctum* and *Trichoderma lignorum*. Phytochemistry, 8: 2405-2410.

Behling, R.A. and **Fischer, A.G.** 1980. Formation of phenylalanylserine and cyclo-phenylalanylserine by protoplasts of *Gliocladium virens*. *Int. J. Biochem.*, 11: 457-458.

Bell, M.R., Johnson, J.R., Wildi, B.S. and **Woodward, R.B.** 1958. The structure of gliotoxin. *J. Amer. Chem. Soc.*, 80: 1001.

Belinck, C. 1980. Mineralization of phenmediphan and derivatives by Trichoderma viride. Immobilization of ^{14}C residues. Effect on biological activity. *Chem. Abs.*, 92: 175750.

Benezet, H.J. and **Matsumura, F.** 1974. Factors influencing the metabolism of mexacarbate by microorganisms. *J. ag. Food Chem.*, 22: 427-430.

Berestetskii, O.A., Patyka, V.F. and **Nadkernichnyi, S.P.** 1978. Phytotoxic properties of fungi of the Trichoderma Pers. Genus. *Chem. Abs.*, 88: 148647.

Berg, D.H., Massing, R.P., Hoehn, M.M., Boeck, L.D. and **Hamil, R.L.** 1976. A30641, a new epidithiodiketopiperazine with antifungal activity. *J. Antibiotics*, 29: 394-397.

Bergman, O. and **Nilsson, T.** 1971. Reduction of microbial deterioration in outside chip storage by alkali treatment. *Chem. Abs.*, 74: 55422.

Berk, S. 1951. Effect of fungus growth on the tensile strength of polyvinyl chloride films plasticised with three plasticizers. *Chem. Abs.*, 45: 388f.

Betina, V. and **Spisiakova, J.** 1976. Suppression of photo-induced sporulation in Trichoderma viride by inhibitors. *Folia Microbiol.*, 21: 362-70.

Bilai, V.I. 1956. Trichoderma Pers. Volatile antibiotics in fungi of the genus *Trichoderma*. *Microbiol.* (Moscow) Eng. trans., 25: 458-465.

Bilai, V.I., Pidoplichko, M.M., Gutirya, V.S., Bukhalo, A.S., V'yun, G.A., Galick, P.M., Koval, E.Z., Masumyan, V. Ya. and **Mil'ko, O.O.** 1965. Petroleum hydrocarbons as the source of carbon for soil mycelial microscopic fungi. *Chem. Abs.*, 63: 7384.

Blight, M.M., Coppen, J.J.W. and **Grove, J.F.** 1968. The biogenesis from mevalonic acid, of the steroidal antifungal metabolite viridin. *Chem. Commun.*, 1117-8.

Bodo, B., Rebuffat, S., El Hajji, M. and **Davoust, D.** 1985. Structure of trichorzianine AIIIc, an antifungal peptide from *Trichoderma harzianum*. *J. Amer. Chem. Soc.*, 107: 6011-6017.

Boheim, G., Hanke, W. and **Jung, G.** 1983. Alamethicin pore formation: voltage-dependent flip-flop of α-helix dipoles. *Biophys. Struct. Mech.*, 9: 181-91.

Borel, J.F., Feurer, C., Gubler, H.U. and **Stähelin, H.** 1976. Biological effects of cyclosporin A: a new antilymphocytic agent. *Agents and Actions*, 6: 468-475.

Brewer, D., Calder, F.W., Jones, G.A., Tanguay, D. and **Taylor, A.** 1986. The effect of nickelous and other metal ions on the inhibition of rumen bacterial metabolism by 3-(3'-isocyanocyclopent-2-enylidene)-propionic acid and related isocyanides. *Appl. Environ. Microbiol.*, 51: 138.

Brewer, D., Feicht, A., Taylor, A., Keeping, J.W., Taha, A.A. and **Thaller, V.** 1982. Ovine ill-thrift in Nova Scotia. 9. Production of experimental quantities of isocyanide metabolites of *Trichoderma hamatum*. *Can. J. Microbiol.*, 28: 1252-1260.

Brewer, D., Hannah, D.E. and **Taylor, A.** 1966. The biological properties of 3.6-epidithiadiketopiperazines. Inhibition of growth of Bacillus subtilis by gliotoxins, sporidesmins and chetomin. *Can. J. Microbiol.*, 12: 1187-1195.

Brewer, D., Hanson, A.W., Shaw, I.M., Taylor, A. and **Jones, G.A.** 1979. A crystalline, toxic, peptide metabolite of *Trichoderma* spp. isolated from soil. *Experientia*, 35: 294-5.

Brewer, D. and **Taylor, A.** 1980. Ovine ill-thrift in Nova Scotia. 6. Quantitative description of the fungal flora of soils of permanent pasture. *Proc. N. S. Inst. Sci.*, 30: 101-133.

Brewer, D. and **Taylor, A.** 1981. Ovine ill-thrift in Nova Scotia. 7. Trichoderma hamatum isolated from pasture soil. *Mycopathol.*, 76: 167-173.

Brian, P.W. 1944. Production of gliotoxin by *Trichoderma viride*. Nature (Lond.), 154: 667.

Brian, P.W., Curtis, P.J., Hemming, H.G. and **McGowan, J.C.** 1946. The production of viridin by pigment forming strains of *Trichoderma viride*. *Ann. Appl. Biol.*, 33: 190-200.

Brian, P.W., Curtis, P.J., Howland, S.R., Jeffreys, E.G. and **Raudnitz, H.** 1951. Three new antibiotics from a species of Gliocladium. *Experientia,* 7: 266-267.

Brown, L.R. and **Pabst, G.S.** 1977. Biodegradation of stainless steel and aluminium alloys. Chem. Abs. 87: 188155.

Brückner, H., Graf, H. and **Bokel, M.** 1984. Paracelsin: characterization by NMR spectroscopy and circular dichroism, and hemolytic properties of a peptaibol antibiotic from the cellulolytically active mold *Trichoderma reesei.* Part B. *Experientia,* 40: 1189-1197.

Brückner, H., König, W.A., Greiner, M. and **Jung, G.** 1979. The sequences of the membrane-modifying peptide antibiotic trichotoxin A-40. *Angew. Chem.,* 91: 508-9.

Brückner, H. and **Przybylski, M.** 1984. Methods for the rapid detection, isolation and sequence determination of "peptaibols" and other aib-containing peptides of fungal origin. I. Gliodeliquescin A from *Gliocladium deliquescens. Chromatographia,* 19: 188-199.

Burge, H.A., Solomon, W.R., and **Boise, J.R.** 1980. Microbial prevalence in domestic humidifiers. *Appl. Environ. Microbiol.,* 39: 840-844.

Butz, R.G., Atallah, Y.H., Yu, C.C. and **Calo, C.J.** 1983. Environmental safety assessment of dipropyleneglycol dibenzoate. *Chem. Abs.,* 98: 138610.

Cass, O.W. 1949. Fungicide comprising 1-methoxy-4-chloro-2-butene U.S. 2462830; Fungicidal composition U.S. 2465061.

Chakrabarty, S. and **Chandra, A.L** 1979. Antifungal activity of A-7 a new tetraene antibiotic. *Chem. Abs.,* 91: 754.

Chen, Yuh-Lin. 1980. Dissipation of herbicide Butachlor in water and soil. *Chem. Abs.,* 92: 168858.

Claydon, N., Grove, J.F. and **Pople, M.** 1985. Elm bark beetle boring and feeding deterrents from Phomopsis oblongata. *Phytochemistry,* 24: 937-943.

Collins, R.P. and **Halim, A.F.** 1972. Characterization of the major aroma constituent of the fungus *Trichoderma viride* (Pers.). *J. ag. Food Chem.,* 20: 437-438.

Colwell, R.R., Walker, J.D. and **Nelson, Jr., J.D.** 1974. Microbial ecology and the problem of petroleum degradation in Chesapeake Bay. *Chem. Abs.,* 80: 118116.

Cook, C.D. and **Harrington, R.** 1948. Growth of *Trichoderma* sp. on cork. Product. Eng., 19: 107.

Couch, R.W., Gramlich, J.V., Davies, D.E. and **Funderburk, H.H.** 1965. The metabolism of atrazine and simazine by soil fungi. *Chem. Abs.,* 63: 3554h.

Cserjesi, A.J. and **Rolf, J.W.** 1976. Toxicity tests of some chemicals against certain wood-staining fungi. *Chem. Abs.,* 84: 100690.

Daines, R.H. 1937. Antagonistic action of *Trichoderma lignorum* on *Actinomyces scabies* and *Rhizoclonia solani.* Am. Potato J., 14: 85-93.

Dao Cong Dan, Fanter, C. and **Philipp, B.** 1980. Enzymic and acid hydrolytic degradation of cross-linked cellulose samples. *Chem. Abs.,* 93: 169872.

Davet, P. 1980. Antagonistic activity and susceptibility to pesticides of some fungi associated with *Sclerotinia minor* sclerotia. *Chem. Abs.,* 92: 89175.

Davet, P. 1981. Effects of some pesticides on the colonization of a substrate by *Trichoderma harzianum* Rifai in the presence of other soil fungi. *Soil Biol. Biochem.,* 13: 513-517.

Davis, D.E., Pillai, C.G.P. and **Truelove, B.** 1976. Effects of prometryn, diuron, flumeturon and MSMA on Chlorella and two fungi. *Weed Sci.,* 24: 587-593.

Davoust, D., Bodo, B., Rebuffat, S. and **Platzer, N.** 1983. High field NMR study of antibiotic peptides: ^{1}H assignment of trichorzianine A1 spectra by 2D experiments. *Biochem. Biophys. Res. Commu.,* 116: 1-8.

Dennis, C. and **Webster, J.** 1971a. Antagonistic properties of species groups of Trichoderma. II. Production of volatile antibiotics. *Trans. Brit. Mycol. Soc.,* 57: 41-48.

Dennis, C. and **Webster, J.** 1971b. Antagonistic properties of species-groups of Trichoderma. III. Hyphal interaction. *Trans. Brit. Mycol. Soc.,* 57: 363-369.

Dinulescu, M. 1979. Mechanisms of action of micromycetes on wood. *Chem. Abs.,* 90: 100276.

Doi, N., Yamaguchi, J. and **Kurata, K.** 1972. Cellulases of the genus Hypocrea and its allies 2. *Chem. Abs.,* 77: 58530.

Dreyfuss, M., Harri, E., Hofmann, H., Kobel, H., Pache, W. and **Tscherter, H.** 1976. Cyclosporin A and C. New metabolites from Trichoderma polysporum (Link ex Pers.) Rifai. *Eur. J. Appl. Microbiol.,* 3: 125-133.

Elad, Y., Chet I. and **Katan, J.** 1980. Trichoderma harzianum: a biocontrol agent effective against *Sclerotium rolfsii* and *Rhizotonia solani. Phytopathology.* 70: 119-121.

Fox, R.O. and **Richards, F.M.** 1982. A voltage-gated ion channel model inferred from the crystal structure of alamethicin at 1.5 A° resolution. *Nature* (Lond.), 300: 325-330.

Fuji, K., Fujita, E., Takaishi, Y., Fujita, T., Arita, I., Komatsu, M. and **Hiratsuka, N.** 1978. New antibiotics trichopolyns A and B; isolation and biological activity. *Experientia,* 34: 237-9.

Fujita, T., Takaishi, Y., Okamura, A., Fujita, E., Fuji, K., Hiratsuka, N., Komatsu, M. and **Arita, I.** 1981. New peptide antibiotics, trichopolyns I and II, from *Trichoderma polysporum. J. Chem. Soc. Chem. Commun.,* 585-7.

Fujita, T., Takaishi, Y. and **Shiromoto, T.** 1979. New peptide antibiotic, hypelcin A, from Hyprocrea peltata. *J. Chem. Soc., Chem. Commun.,* 413-414; *Chem. Pharm. Bull.,* 32: 2870.

Fujita, T., Takaishi, Y., Moritoki, H., Ogawa, T. and **Tokimoto, K.** 1984a. Fungal metabolites. I. Isolation and biological activities of hypelcins A and B (growth inhibitors against *Lentinus edodes)* from *Hypocrea peltata. Chem. Pharm. Bull.*, 32: 1822-8.

Fujita, T., Takaishi, Y., Takeda, Y., Fujiyama, T. and **Nishi, T.** 1984b. Fungal metabolites. II. Structural elucidation of minor metabolites, valinotricin, cyclonerodiol oxide, epicyclonerodiol oxide from *Trichoderma polysporum. Chem. Pharm. Bull.*, 32: 4419-4425.

Fujiwara, A., Okuda, T., Masuda, S., Shiomi, Y., Migamoto, C., Sekine, Y., Tazoe, M. and **Fujiwara, M.** 1982. Fermentation, Isolation and Characterization of isonitrile antibiotics. *Agric. Biol. Chem.*, 46: 1803-1809.

Fukuyama, T. and **Yung, Y.M.** 1981. Total synthesis of (±) methyl 3-(3-isocyano-6-oxabicyclo[3,1,0]hex-2-en-5-yl)-2-propenoate. *Tet. Let.*, 3759-60.

Gams, W. 1971b. Tolypocladium, eine hypomycetengattung mit geschwollenen phialiden. *Personnia*, 6: 185-191.

Gams, W. 1971a. Cephalosporium artige Schimmelpilze. Gustov Fischer Verlag, Stuttgart, p. 19.

Gatenback, S. 1958. Incorporation of labelled acetate in emodin in *Penicillium islandicum. Acta Chem. Scand.*, 12: 1211-1214.

Gauze, G.F., Terekhova, L.P., Maksimova, T.S., Brazhnikova, M.G., Fedorova, G.B. and **Borisova, V.N.** 1983. Screening of new antibiotics from a group of cyclosporins. *Antibiotiki*, 28: 243-5.

Gershon, H., Shanks, L. and **de Angelis, A.** 1979. Antifungal properties of n-alkoxyacetic acids and their methyl esters. *J. Pharm. Sci.*, 68: 82-84.

Gisin, B.F., Davis, D.G., Borowska, Z.K., Hall, J.E. and **Kobayashi, S.** 1981. Synthesis of the major component of alamethicin. *J. Amer. Chem. Soc.*, 103: 6373-7.

Glad, G., Goeransson, B., Popoff, T., Theander, O. and **Tortenssen, N.T.L.** 1981. Decomposition of linuron by fungi isolated from soil. *Swed. J. Agric. Res.*, 11: 127-134.

Godtfredsen, W.O. and **Vangedal, S.** 1965. Trichodermin, a new sesquiterpene antibiotic. *Acta Chem. Scand.*, 19: 1088-1102.

Golder, W.S. and **Watson, T.R.** 1980. Lanosterol derivatives as precursors in the biosynthesis of viridin. Part 1. *J. Chem. Soc.*, (Perkin Trans. I), 422-425.

Göttfert, J. and **Korte, F.** 1978. Wachstum von Hypocrea cf. pilulifera Webster St. Con. unter verschiedensen Kulterbedingunger in anwesenheit von Methabenzthiazuron. *Chemosphere*, 7: 881-92.

Gordon, M.Y. and **Singer, J.W.** 1979. Selective effects of cyclosporin A on colony-forming lymphoid and myeloid cells in man. *Nature* (Lond.), 279: 433-4.

Greenhalgh, R., Meier, R., Blackwell, B.A., Miller, J.D., Taylor, A. and **ApSimon, J.W.** 1984. Minor metabolites of *Fusarium roseum* (ATCC 28114). *J. ag. Food Chem.*, 32: 1261-4.

Griffin, G.J.L. and **Mivetchi, H.** 1977. Biodegradation of ethylene/vinyl acetate copolymers. *Chem. Abs.*, 87: 23921.

Grove, J.F., McCloskey, P. and **Moffatt, J.S.** 1966. Viridin. Part V. Structure. *J. Chem. Soc.* (C), 743-747.

Grove, J.F., Moffat, J.S. and **Vischer, E.B.** 1965. Viridin. Part I. Isolation and characterization. *J. Chem. Soc.* (C), 3803-3811.

Gudin, C. and **Chater, K.W.A.** 1977. Isolation of Trichoderma hamatum growing on ferric hydroxide mud impregnated with gas-oil. *Environ. Pollut.*, 14: 1-4.

Han, Y.W. and **Anderson, A.W.** 1975. Semi-solid fermentations of rye-grass straw. *Appl. Microbiol.*, 30: 930-4.

Hanson, A.W., McAlees, A.J. and **Taylor, A.** 1985. Ovine ill-thrift in Nova Scotia. Part 10. Palladium and rhodium complexes as reagents in the investigation of isocyanide metabolites of *Trichoderma hamatum. J. Chem. Soc.*, (Perkin Trans. I), 441-446.

Hanson, J.R. and **O'Leary, M.A.** 1981. New piperazinedione metabolites of *Gliocladium deliquescens. J. Chem. Soc.* (Perkin Trans. I), 218-220.

Hanson, J.R. and **Wadsworth, H.J.** 1979. Biosynthesis of demethoxyviridin. *J. Chem. Soc. Chem. Commun.*, 360-1.

Henderson, M.E.K. and **Duff, R.B.** 1963. The release of metallic and silicate ions from minerals, rocks and soils by fungal activity. *J. Soil Sci.*, 14: 236-46.

Hibben, C.R. and **Stotzky, G.** 1969. Effects of ozone on the germination of fungus spores. *Can. J. Microbiol.*, 15: 1187-1196.

Hodges, R. and **Shannon, J.S.** 1966. The isolation and structure of sporidesmin C. *Aust. J. Chem.*, 19: 1059-66.

Hou, C.T., Ciegler, A. and **Hesseltine, C.W.** 1972. New mycotoxin, trichotoxin A, from *Trichoderma viride* isolated from southern leaf blight-infected corn. *Appl. Microbiol.*, 23: 183-185.

Howell, C.R. and **Stipanovic, R.D.** 1983. Gliovirin, a new antibiotic from *Gliocladium virens*, and its role in the biological control of *Pythium ullimum. Can. J. Microbiol.* 29: 321-324.

Hutchinson, S.A. and **Cowan, M.E.** 1972. Identification and biological effects of volatile metabolites from cultures of *Trichoderma harzianum. Trans. Brit. Mycol. Soc.*, 59: 71-77.

Hussain, S.A., Noorani, R. and **Qureshi, I.** 1975. Microbial chemistry. Part I. Isolation and characterization of gliotoxin, ergosterol, palmitic acid and mannitol metabolic products of *Trichoderma hamatum* Bainier. *Pak. J. Sci. Ind. Res.*, 18: 221-223.

Igaue, I. 1966. Fungal enzymes active in degrading barley β-glucans. *Chem. Abs.*, 65: 961.

Itoh, Y., Kodama, K., Furuya, K., Takahashi, S., Haneishi, T., Takiguchi, Y. and **Arai, M.** 1980. A new sesquiterpene antibiotic, heptelidic acid: producing organisms, fermentation, isolation and characterization. *J. Antibiotics*, 33: 468-478.

Itoh, Y., Takahashi, S. and **Arai, M.** 1982. Structure of gliocladic acid. *J. Antibiotics,* 35: 541-2.

Jackson, R.B. 1973. Metabolism of allyl alcohol by Trichoderma viride. *J. Gen. Appl. Microbiol.,* 19: 41-54.

Joffe, A.Z. 1974. Toxicity of *Fusarium poae* and *F. sporotrichioides* and its relation to alimentary toxic aleukia. In Mycotoxins Ed. I. F. H. Purchase. Elsevier, Amsterdam, 229-262.

Johnson, J.R., Bruce, W.F. and **Dutcher, J.D.** 1943. Gliotoxin, the antibiotic principle of Gliocladium fimbriatum. I. Production, physical and biological properties. *J. Amer. Chem. Soc.,* 65: 2005-2009.

Jung, G., Brückner, H. and **Schmidt, H.** 1979. Properties of the membrane modifying polypeptide antibiotics alamethicin and trichotoxin A-40. *Struct. Act. Nat. Pept.,* Proc. Fall Meet. Ges. Biol. Chem., 75-114.

Kamal, A., Akhtar, R. and **Qureshi, A.A.** 1971. Biochemistry of microorganisms. XX. 2,5-Dimethoxybenzoquinone, tartronic acid, itaconic acid, succinic acid, pyrocalciferol, epifriedelinol, lanosta-7,9(11),24-triene-3β, 21-diol, trichodermene A, methyl 2, 4, 6-octatriene and cordycepic acid, *Trichoderma* metabolites. *Pak. J. Sci. Ind. Res.,* 14: 71-78.

Kanivets, I.I., Khariton, E.G. and **Tul'chinskaya, E.M.** 1940. Increased yield of sugar-beet, oats and lupine by soil infected with *Trichoderma lignorum. Microbiology* (USSR), 9: 143-51.

Katayama, T., Minato, H., Ishi, K. and **Kondo, E.** 1977. A new antibiotic, trichorin A. *J. Antibiotics,* 30: 430-431.

Kawasaki, C. and **Ito, Y.** 1966. Hydrolysis of chitin by fungal enzyme preparations. *Chem. Abs.,* 64: 20095.

Katz, E. 1983. Suzukacillin A: Sequenzierung und Konformationsuntersuchungen eines membranmodifizierten Eikosapeptids, Thesis. Tubingen, W. Germany.

von Kerner-gang, W., and **Hoffmann, H.** 1982. Untersuchungen zum Verhalten von Schimmelpilzen gegenüber Klebstoffen für Holzwerkstoffe. *Material und Organ.,* 17: 253-268.

Khimerik, T. Yu and **Koval, E.Z.** 1977. Study of fungal resistance of some road building materials. *Mikrobiol. Zh.* (Kiev), 39: 84-87.

Kikuchi, T., Mimura, T., Harimaya, K., Yano, H., Arimoto, T., Masada, Y. and **Inoue, T.** 1974. Volatile metabolite of aquatic fungi. Identificaton of 6-pentyl-α-pyrone from *Trichoderma* and *Aspergillus* Species. *Chem. Pharm. Bull.,* 22: 1946-1948.

Kirby, G.W., Robins, D.J., Sefton, M.A. and **Talekar, R.R.** 1980. Biosynthesis of Bisdithiobis-(methylthio)-gliotoxin, a new metabolite of *Gliocladium deliquescens. J. Chem. Soc.,* (Perkin Trans. I), 119-121.

Kishi, Y., Fukuyama, T. and **Nakatsuka, S.** 1972. A new method for the synthesis of epidithiodiketopiperazines. *J. Amer. Chem. Soc.,* 95: 6490-6492.

Kleinkauf, H. and **Rindfleisch, H.** 1975. Non-ribosomal biosynthesis of the cyclic octadecapeptide alamethicin. *Acta Microbiol. Acad. Sci. Hung.,* 22: 411-418.

Kleus, P.F. and **Lang, J.F.** 1956. Microbiological factors in the preservation of paint. *Chem. Abs.,* 50: 10327d.

Kvasnikov, E.I., Malashenko, Yu. R and **Ramanovskaya, V.A.** 1971. Effect of ethanethiol on the growth of microorganisms. *Chem. Abs.,* 75: 85634.

Leigh, C. and **Taylor, A.** 1976. The chemistry of the epipolythiopiperazine-3, 6-diones. Advances in chemistry series No. 149, Mycotoxins and other fungal related food problems. Ed. J. V. Rodricks. *Amer. Chem. Soc.,* p. 228-275.

Lew, J.D. and **Wilcox, W.W.** 1981. The role of selected deuteromycetes in the soft-rot of wood treated with pentachlorophenol. *Chem. Abs.,* 95: 188856.

Lewis, J.A. and **Papavizas, G.C.** 1984. A new approach to stimulate population proliferation of *Trichoderma* species and other potential biocontrol fungi introduced into natural soils. *Phytopathology,* 74: 1240-1244.

Liss, S.N., Brewer, D., Taylor, A. and **Jones, G.A.** 1985. Antibiotic activity of an isocyanide metabolite of *Trichoderma hamatum* against rumen bacteria. *Can. J. Microbiol.,* 31: 767-772.

Lowe, G., Taylor, A. and **Vining, L.C.** 1966. Sporidesmins. Part VI. Isolation and structure of dehydrogliotoxin a metabolite of *Penicillium terlikowskii. J. Chem. Soc.* (C), 1799-1803.

Madaan, S.L. and **Chohan, J.S.** 1978. Resident mycoflora on pegs of groundnut as effected by seed and soil treatment with fungicides. *Indian J. Mycol. Plant Pathol.,* 8: 149-152.

Manyu, S.K.K. 1980. The physiologically active substance SC2051. *Chem. Abs.,* 93: 112329.

Marasas, W.F.O., Bamburg, J.R., Smalley, E.B., Strong, F.M., Ragland, W.L and **Degurse, P.E.** 1969. Toxic effects on trout, rats and mice of T_2-toxin produced by the fungus *Fusarium trincinctum. Toxicol. Appl. Pharmacol.,* 15: 471-82.

Matsumora, F. and **Bousch, G.M.** 1968. Degradation of insecticides by a soil fungus, *Trichoderma viride. J. Eccon. Entomol.,* 61: 610-612.

Mazur, F.F. 1979. Effect of *Trichoderma viride* on synthetic rubbers and polyethylene. *Chem. Abs.,* 90: 204954.

Menzel, A.E.O., Wintersteiner, O. and **Hoogerheide, J.C.** 1944. The isolation of gliotoxin and fumigacin from culture filtrates of *Aspergillus fumigatus. J. Biol. Chem.,* 152: 419-429.

Merlier, O.A.M., Boirie, J.M., Pons, J.B. and **Renaud, C.M.** 1985. Strain of *Trichoderma harzianum,* its isolation, its culture, peptides or compounds produced by this strain and application of this strain and these peptides or the product produced by the culture process as a means for biological control in the form of an agricultural fungicide. *Chem. Abs.,* 102: 183747.

Merrill, W., French, D.W. and **Hossfield, R.L** 1965. Wood fibreboard studies. II. Effects of common molds on the physical and chemical properties of wood fibreboard. *Tappi,* 48: 470-474.

Meyer, C.E. and **Reusser, F.** 1967. A polypeptide antibacterial agent isolated from *Trichoderma viride. Experientia,* 23: 85-6.

Miller, P.A., Milstrey, K.P. and **Trown, P.W.** 1968. Specific inhibition of viral ribonucleic acid replication by gliotoxin. *Science,* 159: 431-2.

Mirocha, C.J. 1983. Developments in Food Science. 4. Trichothecenes chemical, biological and toxicological aspects. Ed. Y. Uneno, Elsevier, Amsterdam, p. 177-194.

Mitchell, C.P. and **Dix, N.J.** 1975. Growth and germination of *Trichoderma* spp. under the influence of soil fungistasis. *Trans. Brit. Mycol. Soc.*, 64: 235-41.

Mitzutani, S., Kuwata, M., Hatori, H. and **Okada, S.** 1980. Storage of chrome leather. *Chem. Abs.*, 92 60360.

Moelhave, L. 1977. The relation between the tree formaldehyde concentration in stored (urea-formaldehyde) chipboard and the formaldehyde concentration in the air. *Holzforsch Holzverwert*, 29: 73-4.

Moffatt, J.S., Bu'Lock, J.D. and **Yuen, T.H.** 1969. Viridiol, a steroid-like product from *Trichoderma viride*. *Chem. Commun.*, 839.

Mohr, H. and **Kleinkauf, H.** 1978. Alamethicin biosynthesis. Acetylation of the amino terminus and attachment of phenylalaninol. *Biochim. Biophys. Acta*, 526: 375-386.

Moreau, R. and **Augier, J.** 1962. The utilization of vanillin by soil microorganisms. *Compt. Rend.*, 254: 555-7.

Moore-Landecker, E. and **Stotzky, G.** 1972. Inhibition of fungal growth and sporulation by volatile metabolites from bacteria. *Can. J. Microbiol.*, 18: 957-962.

Moss, M.O., Jackson, R.M. and **Rogers, D.** 1975. The characterization of 6-(pent-1-enyl)-α-pyrone from *Trichoderma viride*. *Phytochemistry*, 14: 2706-2708.

Mukasheva, G.M. 1976. Action of hexachlorobutadiene on pure cultures of microscopic fungi. *Chem. Abs.*, 82: 11637.

Müllbacher, A. and **Eichner, R.D.** 1984. Immunosuppression *in vitro* by a metabolite of a human pathogenic fungus. *Proc. Natl. Acad. Sci.* (U.S.A.), 81: 3855-7.

Nagaraj, R. and **Balaram, P.** 1981a. Solution phase synthesis of alamethicin I. *Tetrahedron*, 37: 1263-1270.

Nagaraj, R. and **Balaram, P.** 1981b. Alamethicin, a transmembrane channel. *Acc. Chem. Res.*, 14: 356-62.

Nago, H. and **Ishikawa, H.** 1970. Anthraquinone pigments and antibiotics formed by Hypocrea austro-grandis. *Chem. Abs.*, 75: 18551.

Nair, M.S.R. and **Carey, S.T.** 1979. Metabolites of Pyrenomycetes. XI. Polyketides from Hypocreales. *Mycologia*, 71: 1089-96.

Nair, M.S.R., Carey, S.T. and **Ananthasubramanian, L.** 1982. Metabolites of pyrenomycetes. XV. Biogenesis of the antitumor antibiotic, (+) R-avellaneol. *J. Nat. Prod.*, 45: 644-5.

Nazarova, E.V. and **Zakharova, I. Y.** 1982. Isolation and characterization of a *Gliocladium zaleskii* 11313 phytotoxic substance. *Mikrobiol. Zh.* (Kiev), 44: 43-48.

Nelson, E.E. 1972. Effect of urea and wood shavings on populations of soil microfungi especially Trichoderma spp. *Microbios.*, 5: 69-72.

Nelson, E.E. 1976. Effect of urea on *Poria weirii* and soil microbes in an artificial system. *Soil Biol. Biochem.*, 8: 51-53.

Nilsson, T. and **Assarsson, A.** 1970. Treatment of wood chips with *Trichoderma lignorum* to descrease resin content. U.S. 3486969; *Chem. Abs.*, 72: 102034.

Nobuhara, M., Tazima, H., Shudo, K., Itai, A., Okamoto, T. and **Iitaka, Y.** 1976. A fungal metabolite, novel isocyanoepoxide. *Chem. Pharm. Bull.*, 24: 832-834.

Ooka, T. 1977. Physiologically active substance No. 1037. *Chem. Abs.*, 87: 166000.

Ooka, T., Shimojima, Y., Akimoto, T., Takeda, I., Senoh, S. and **Abe, J.** 1966. A new antibacterial peptide suzukacillin. *Agric. Biol. Chem.*, 30: 700-702.

Ooka, T. and **Takeda, I.** 1974. The relationship between α-aminoisobutyrate and L-valine for the suzukacillin formation. *Agric. Biol. Chem.*, 38: 19-27.

Pandey, R.C., Cook, J.C. and **Rinehart, K.L.** 1977. High resolution and field desorption mass spectrometry studies and revised structures of alamethicins I and II. *J. Amer. Chem. Soc.*, 99: 8469-8483.

Parry, R.J. and **Hanh Phuoc Buu.** 1982. Biosynthesis of an isonitrile acid from Trichoderma hamatum. *Tet. Let.*, 1435-8.

Pashenko, A.A., Vorenkov, M.G., Koval, E.Z., Vlasova, N.N., Shevchenko, L.A. and **Sviderskii, V.A.** 1978. Study of the resistance of organosilicon protective coatings to molds. *Chem. Abs.*, 89: 192306.

Patil, B.C., Sharma, R.P., Salunke, D.K. and **Salunke, K.** 1972. Evaluation of solanine toxicity. *Chem. Abs.*, 77: 148228.

Patil, K.C., Matsumura, F. and **Boush, G.M.** 1970. Degradation of Endrin, Aldrin and DDT by soil microorganisms. *Appl. Microbiol.*, 19: 879-881.

Pitel, D.W., Arsenault, G.P. and **Vining, L.C.** 1971. Cyclonerodiol, a sesquiterpene metabolite of *Gibberella fujikuroi*. *J. Antibiot.*, 24: 483-4.

Peeples, J.L. 1972. Effect of the herbicide EPTC (ethyl N,N-dipropylthiocarbamate) on growth responses, antagonism and pathogenesis associated with *Sclerotium rolfsii* and *Trichoderma viride*. *Chem. Abs.*, 76: 82068.

Petcher, T.J., Weber, H.P. and **Ruegger, A.** 1976. Cyrstal and molecular structure of an iodo derivative of the cyclic undecapeptide cyclosporin A. *Helv. Chim. Acta*, 59: 1480-1488.

Pettersson, G. 1964. Synthesis of 2,3-dihydroxy-5,6-dimethyl-1,4-benzoquinone and its monomethyl ether. *Acta Chem. Scand.*, 18: 2309-2312; *idem*, 1965, New phenolic metabolites from *Gliocladium roseum*, *ibid.* 19: 2303-2308.

Pommer, E.H. 1966. The effect of pyramin on soil fungi. *Chem. Abs.*, 64: 1287f.

Popescu, G. 1979. Protection of corrugated carton wrapping, I. Manufacture of microorganism resistant corrugated cartons. *Chem. Abs.*, 90: 7870.

Pratt, B.H., Sedgley, J.H., Heather, W.A. and **Shepherd, C.J.** 1972. Oospore production in *Phytophthora cinnamomi* in the presence of *Trichoderma koningii. Aus. J. Biol. Sci.*, 25: 861-3.

Reeves, R.J. and **Jackson, R.M.** 1972. Induction of *Phytophthora cinnamomi* oospores in soil by *Trichoderma viride. Trans. Brit. Mycol. Soc.*, 59: 156-159.

Reusser, F. 1966. Biosynthesis of antibiotic U-22324 cyclic polypeptide. *J. Biol. Chem.*, 242: 243-7.

Rifai, M.A. 1969. A revision of the genus *Trichoderma. Mycol. Papers* 116: 1-56.

Rightsel, W.A., Schneider, H.G., Sloan, B.J., Graf, P.R., Miller, F.A., Bartz, G.R., Ehrlich, J. and **Dixon, E.J.** 1964. The antiviral activity of gliotoxin and gliotoxin acetate. *Nature (Lond.). 204: 1333-4.*

Rüegger, A., Kuhn, M., Lichti, H., Loosli, H., Huguenin, R., Quiquerez, C. and **von Wartburg, A.** 1976. Cyclosporin A ein immunsuppressiv wirksamer Peptidmetabolit aus *Trichoderma polysporum* (Link ex Pers.) Rifai. *Helv. Chim. Acta*, 59: 1075-1092.

Ryu, D.D.Y. and **Mandels, M.** 1980. Cellulases: biosynthesis and applications. *Enzyme Microb. Technol.*, 2: 91-102.

Saccardo, P.A. 1883. Sylloge fungorum, 2: 469, 527, 529, 536.

Saito, M., Yamanishi, T. and **Tsuruta, O.** 1981. Studies on the odor substances of fungi. Part I. Identification of the fungal odors produced on the synthetic medium. *Chem. Abs.*, 94: 79943.

Sakaguchi, K., Kurani, R. and **Murata, M.** 1976. Assimilation of formaldehyde and other C_1 compounds by *Gliocladium deliquescens* and *Paecilomyces varioti. Chem. Abs.*, 85: 2305.

Sakata, K., Masago, H., Sakurai, A. and **Takahashi, N.** 1982. Isolation of aspirochlorine (= antibiotic A30641) possessing a novel dithioketopiperazine structure from *Aspergillis flavus. Tet. Let.*, 2095-8.

Sax, N.I. 1968. Dangerous properties of industrial materials. 3rd ed. Van Nostrand Reinhold, New York, p. 1071.

Schappert, K.T. and **Khachatourians, G.E.** 1983. Effects of fusariotoxin T_2 on *Saccharomyces cerevisiae* and *Saccharomyces carlsbergensis. Appl. Environ. Microbiol.*, 45: 862-7.

Schmitt, H. and **Jung, G.** 1985. Total synthesis of the α-helical eicosapeptide antibiotic alamethicin. *Liebigs Ann. Chem.*, 321-344.

Selivokhin, P.I., Bolonina, E.I. and **Zemlyanskii, N.N.** 1974. Organotin compounds as antiseptics for film materials. *Chem. Abs.*, 80: 56063.

Senior, E., Bull, A.T. and **Slater, J.H.** 1976. Enzyme evolution in a microbial community growing on the herbicide dalapon. *Nature* (Lond.). 263: 476-9.

Shaw, I.M. and **Taylor, A.** 1986. The chemistry of peptides related to metabolites of *Trichoderma* spp. 2. An improved method of characterization of peptides of 2-methylalanine. *Can. J. Chem.*, 64: 164-173.

Shteinberg, B.I., Trakhtenberg, S.I., Datsyuk, N.M., Kovalyuk, E.K., Gura, I.S. and **Shakh, E.S.** 1983. Biological stability of poly(vinyl alcohol)-based polymers. *Mikrobiol. Zh.* (Kiev), 45: 20-24.

Sierota, Z.H. 1977. Yield of dry mycelium of *Trichoderma viride* Pers. ex Fr. on some carbon and nitrogen sources. *Eur. J. For. Pathol.*, 7: 65-76.

Singh, R., Iyenga, L. and **Rao, A.V.S.P.** 1977. Effect of insecticides on fungal enzymes. *J. Gen. Appl. Microbiol.*, 23: 119-26.

Slater, G.P., Haskins, R.H., Hagge, L.R. and **Nesbitt, L.R.** 1967. Metabolic products from a *Trichoderma viride* Pers. ex. Fries. *Can. J. Chem.*, 45: 92-96.

Sokoloff, B. and **Toda, Y.** 1967. Antiviral antibiotic from *Trichoderma todica* and its production method. *Chem. Abs.*, 67: 62990.

Spencer, H.C., Rowe, V.K. and **McCollister, D.D.** 1950. Dehydroacetic acid. I. Acute and chronic toxicity. *J. Pharamacol. Explt. Therap.*, 99: 57-68.

Stipanovic, R.D. and **Howell, C.R.** 1982. The structure of gliovirin, a new antibiotic from *Gliocladium virens. J. Antibiotics*, 35: 1326.

Stipanovic, R.D. and **Howell, C.R.** 1983. The X-ray crystal structure determination and biosynthesis studies of the antibiotic heptelidic acid. *Tetrahedron*, 39: 1103-7.

Stranks, D.W. 1971. Trichoderma viride enzymic degradation of wood structure. *Chem. Abs.*, 74: 23734.

Stratton, G.W. 1983. Interaction effects of permethrin and atrazine combinations towards several non-target microorganisms. *Bull. Eniron. Contam. Toxicol.*, 31: 297-303.

Suess, A. and **Netzsch-Lehner, A.** 1969. Effect of various micro-organisms on the intensity of decomposition of diesel oil. Z. Pflanzenernaehr. Bodenk., 123: 232-9.

Sukhorukova, Z.A. 1972. Antibiotic properties of fungi isolated from the rhizosphere of barley and oats. *Mikrobiol. Zh.* (Kiev), 34: 602-5.

Tabata, T. and **Kondo, T.** 1977. Protection of Shiitake fungus from mycoparasites by fungicidal agents. 4. Selective antifungal activity of 5-substituted methyl 2-benzimidazole carbamates, 2-aryl- and 2-alkyl-substituted benzimidazole derivatives upon the mycelium of Shiitake fungus and its mycoparasites. *Mokuzai Gakkaishi* 1977, 23: 504-508; *Chem. Abs.*, 88: 33004.

Tamimi, K.M. and **Hutchinson, S.A.** 1975. Differences between the biological effects of culture gases from species of *Trichoderma. Trans. Brit. Mycol. Soc.*, 64: 455-463.

Tamura, A., Kotani, H. and **Naruto, S.** 1975. Trichoviridin and dermadin from Trichoderma sp. TK-1. *J. Antibiotics*, 28: 161-162.

Taylor, A. 1970. The occurrence, chemistry, and toxicology of the microbial peptide-lactones. *Ad. Appl. Microbiol.* 12: 189-276.

Taylor, A. 1971. The toxicology of sporidesmins and other epipolythiadioxpiperazines. In Microbial Toxins. Vol. 7, Ed. S. Kasis, A. Ciegler and S. J. Ajl. Academic Press, New York, p. 363.

Thomson, A.W., Whiting, P.H. and **Simpson, J.G.** 1984. Cyclosporine: immunology, toxicity and pharmacology in experimental animals. *Agents Actions,* 15: 306-27.

Traber, R., Kuhn, M., Loosli, H., Pache, W. and **von Wartburg, A.** 1977. Neue Cyclopeptide aus *Trichoderma polysporum* (Link ex Pers.) Rifai: die Cyclosporine B, D, und E. *Helv. Chim. Acta,* 60: 1568-1578.

Traber, R., Loosli, H., Hofmann, H., Kuhn, M. and **von Wartburg, A.** 1982. Isolierung und Strukturermittlung der neuen Cyclosporine E, F, G, H und I. *Helv. Chim. Acta,* 65: 1655-1677.

Tripathi, R.D., Tripathi, S.C. and **Dixit, S.N.** 1980. Structure activity relationship among some fungitoxic α-napthoquinones of angiosperm origin. *Ag. Biol. Chem.,* 44: 2483-5.

Ueno, Y. 1983. Developments in Food Science. 4. Trichothecenes, chemical, biological and toxicological aspects. Ed. Y. Ueno, Elsevier, Amsterdam, p. 135-146.

Ueno, Y., Nakajima, M., Sakai, K., Ishii, K., Sato, N. and **Shimada, N.** 1973. Comparative toxicology of trichothec mycotoxins: inhibition of protein synthesis in animal cells. *J. Biochem.,* 74: 285-296.

Upjohn Company. 1969. The antibiotic alamethicin. U. K. Patent 1152659.

Usui, M. and **Iida, S.** 1980. Control of pathogenic fungi in the nursery cases of rice young seedlings by chemicals. *Chem. Abs.,* 92: 1505.

Veldre, I., Karpunin, B.I. and **Maasik, I.** 1971. Toxicological characteristics of 5-methylresorcinol. *Chem. Abs.,* 74: 51746.

Verrall, A.F. 1949. Some molds under wood favored by certain toxicants. *J. Agr. Res.,* 78: 695-703.

Vischer, E.B. 1953. The structures of aurantio- and rubro-gliocladin and glioresein. *J. Chem. Soc.,* 815-820.

Wakazawa, T., Niwa, T. and **Ichinose, K.** 1965. Degradation of wood pulp and cotton linters by *Trichoderma koningii* cellulase. *Chem. Abs.,* 62: 16500 h.

Webster, J. and **Lomas, N.** 1964. Does *Trichoderma viride* produce gliotoxin and viridin? *Trans. Brit. Mycol. Soc.,* 47: 535-540.

Weil, C. 1984. Cyclosporin A; review of results in organ and bone marrow transplantation in man. *Med. Res. Rev.,* 4: 221-65.

Weindling, R. 1932. *Trichoderma lignorum* as a parasite of other soil fungi. *Phytopathology,* 22: 837-845.

Weindling, R. 1934. Studies in a lethal principle effect in the parasitic association of *Trichoderma lignorum* on *Rhizoctonia solani* and other soil fungi. *Phytopathology,* 24: 1153-1179.

Wenger, R.M. 1984. Synthesis of cyclosporin. Total synthesis of cyclosporin A and cyclosporin H, two fungal metabolites isolated from the species *Tolypocladium inflatum* Gams. *Helv. Chim. Acta,* 67: 502-525.

Widden, P. and **Abitol, J.J.** 1980. Seasonality of *Trichoderma* species in a spruce-forest soil. *Mycologia,* 72: 775-784.

Whitman, W.B. and **Wolfe, R.S.** 1980. Presence of nickel in factor F_{430} from *Methanobacterium bryantii. Biochem. Biophys. Res. Commun.,* 92: 1196-1201.

Yamamoto, I., Hemmi, T. and **Yamano, T.** 1970. Sesquiterpenoid antibiotics from molds. *Chem. Abs.,* 72: 76058.

Yamamoto, Y., Nitta, K., Oohata, Y. and **Furukawa, T.** 1972. Studies on the metabolic products of a strain of *Aspergillus fumigatus* DH413. V. A new metabolite produced by ethionine inhibition. *Chem. Pharm. Bull.,* 20: 931-5.

Yamano, K. 1979. Observations of fungal attacks on PVC. *Chem. Abs.,* 91: 124303.

Yoshimoto, T., Samejima, M., Kimura, T., Yoshitomi, K. and **Nakanishi, K.** 1984. Growth inhibitors of Trichoderma sp. in hot-water extractives from barks of *Quercus* sp. *Chem. Abs.,* 100: 188827.

Zayed, S.H.A.D., Mostafa, I.Y., Farghaly, M.M., Attaby, H.S.H. and **Adam, Y.M.** 1982. Degradation of trifluorin by *Trichoderma viride. Chem. Abs.,* 97: 174771.

Zoltanska, E. 1984. Effect of some fungicides on selected soil fungi. *Chem. Abs.,* 101: 145899.

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Volume 36, pp. 59-61

PROPAGATION IN VITRO OF 'MICHURINETZ' GRAPES

There has been substantial interest recently in the potential for a wine industry in Nova Scotia (Dial 1979; Cattell 1984; Schreiner 1984/1985). The hardy Russian cultivar *Vitis amurensis* "Michurinetz" has, along with others, been grown for use as a red wine grape at Grand Pré, N.S. It was of considerable interest to begin to develop *in vitro* propagation strategies for such grapes, strategies which might afford a year-round means of true-to-type cloning and of virus eradiction (Barlass, Skene, Woodham and Krake 1982; Mantell, Matthews and Mckee 1985). In this note we report successful maintenance of stock multiple shoot cultures and also high-efficiency rooting *in vitro*.

Dormant budwood of the Michurinetz cultivar was flushed while standing in tapwater at 24-26° C in an 18 h photoperiod for 8-12 days. The resulting expanded leaves were carefully dissected away and surface sterilization of the remaining buds was effected by immersion in sodium hypochlorite (2% w/v), for 6 minutes, followed by 3 rinses of sterile double-distilled water. Buds (3-6 mm long) were inoculated on a standard plant tissue culture medium, consisting of Murashige/Skoog (MS) salt base (Carolina Biologicals) with sucrose (30 $g.L^{-1}$), agar (8 $g.L^{-1}$), thiamine (10 $mg.L^{-1}$), inositol (1 $g.L^{-1}$) and the cytokinin N^6-benzylaminopurine (BAP; Goussard 1982; Chee and Pool 1982; Monette 1983). The pH of media was adjusted to 5.8 prior to autoclaving. Medium (30 mL) was dispensed in 100 ml screw-top glass jars. The culture environment was at 26-28° C with a photoperiod of 18 h, under cool-white fluorescent lamps (9000 lux). The passage time was 4 weeks. Single bud explants formed multiple shoot cultures (Fig. 1) through the development of axillary buds. Such stock cultures have been routinely subcultured for over 2 years.

Table I Shoot multiplication and wet weight in relation to cytokinin dose for shoots of 'Michurinetz' grape.[1] *in vitro*.

BAP (μM)[2]	Mean No. shoots per culture[3]	C.I.[4]	Mean fresh wt. per culture[5] (gm)	C.I.[4]	Callus Index[6]	Frequency of cultures with roots (%)
0	1.79 a	± 0.054	0.540 a	± 0.172	0.14	57
0.01	3.52 b	± 0.800	0.940 b	± 0.250	0.13	61
0.10	2.30 a	± 0.610	0.637 ab	± 0.156	0.26	61
1.00	2.00 a	± 0.030	0.580 ab	± 0.210	1.00	21
2.50	8.61 c	± 2.190	1.860 c	± 0.470	0.88	18
5.00	27.76 d	± 3.940	7.100 d	± 1.420	1.80	56

[1] Standard shoots cultured on MS media + BAP at 26-28° C, photoperiod 18 hours; 9000 lux.
[2] 23-28 replicate shoot per treatment; pooled data from 2 experiments; exception: 14 shoots only survived on 0 BAP.
[3] Similar letters in a vertical column indicate two means are not significantly different (Student t-test $P > 0.05$).
[4] 95% confidence interval.
[5] Initial wet weight = 0.0441 g per shoot (N = 15).
[6] Calculated as follows: a semi-quantitative ranking of the amount of callus on each stem base was used after visual inspection: 0, 1, 2, 3 denoted increasing amounts of callus; for each treatment, these values were summed and divided by the number of replicates to give a number for callus quantity.

For measurement of shoot multiplication, the above medium was used with BAP at 0, 0.01, 0.1, 1.0, 2.5 and 5.0 μM. From the stock cultures, 'standard' microcuttings were harvested, each consisting of a terminal bud, 1-2 cm of stem and 2 expanded leaves. There were 11-18 replicate microcuttings per treatment in each of 2 experiments; not all these survived (Table I, footnote[2]).

After 3 passages measurements were recorded, for each microcutting, of a) total number of shoots greater than 0.5 cm; b) length of the longest shoot; c) fresh weight; d) presence of callus; e) presence of roots.

For rooting trials, the MS salts were reduced to half-strength and BAP was replaced by 4-(indolyl-3) butyric acid (IBA; George and Sherrington 1984; Krul and Mowbray 1984), at 0, 0.25, 2.5 and 5 μM. All other media components were as above. Stock IBA was added to the cooling autoclaved medium through a 0.22 μ Millipore filter system. Rooting medium (40 mL) was dispensed into 100 mL glass jars with plastic screw-top closures. Standard explants for rooting were single shoots, 1-2 cm on length, bearing the terminal bud and 2 expanded leaves. Stems were inserted in the medium near the vessel wall, for periodic observation of emerging root primordia, using a dissecting microscope. Twenty-four shoots were tested on each dose of IBA and the experiment was repeated once.

In shoot multiplication trials, BAP did not significantly promote shoot production at doses less than 2.50 μM, or else gave a weak promotive effect (Table I). A better than four-fold increase in shoot production was observed with 2.50 μM BAP. While very high shoot numbers were produced on 5.0 μM BAP, their stems were short (mean 2.8 cm vs 4.9 cm on 2.5 μM BAP), fasciated and bore distorted leaves. BAP significantly increased the mean fresh weight per culture at 0.01 μM and especially at 2.50 and 5.0 μM (Table I). Callus, at the base of shoots, was produced on all treatments, particularly in the range 1.0-5.0 μM BAP. Rooting was observed on all treatments, but the frequency of rooting bore no clear relationship to cytokinin dose (Table I).

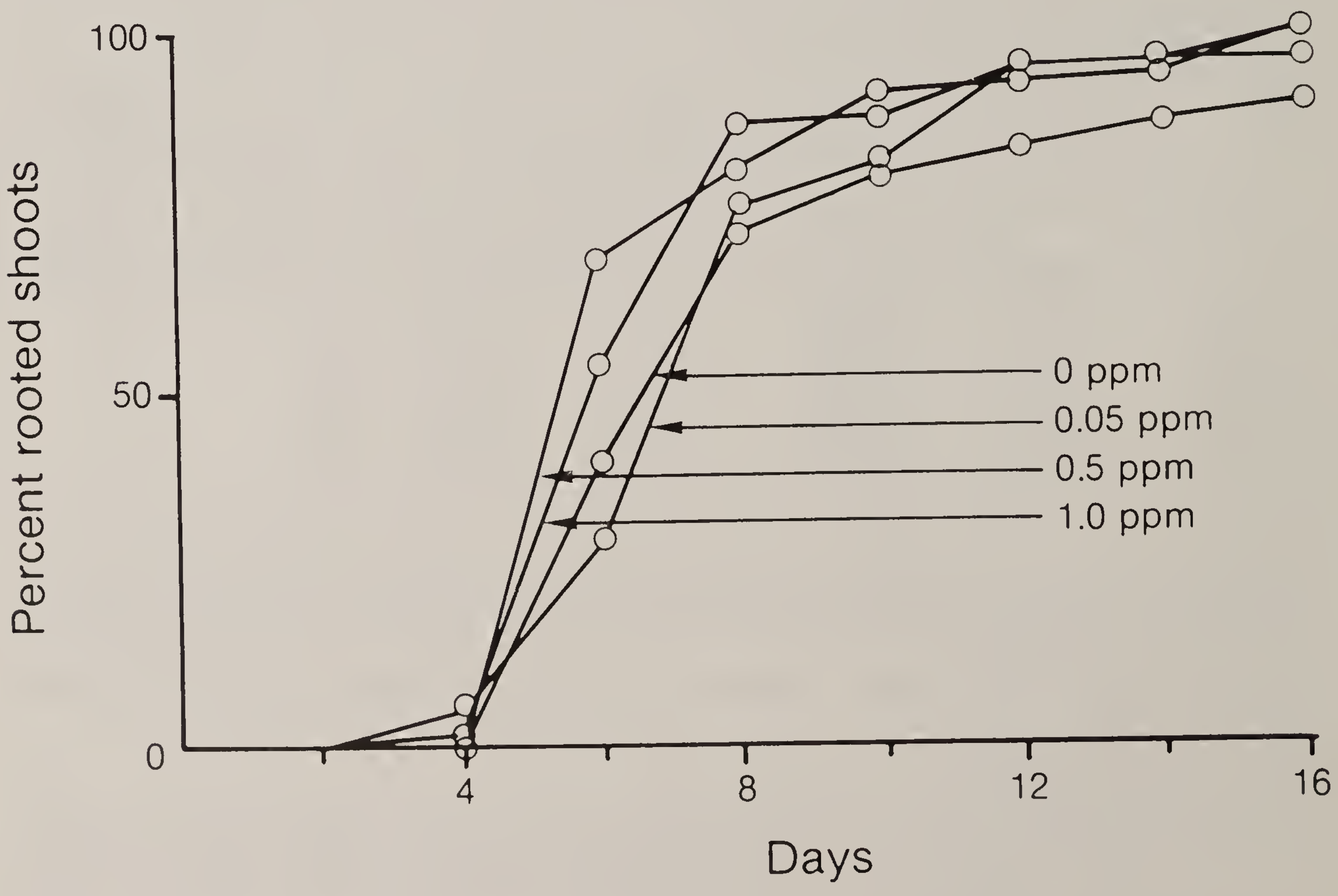


Fig. 3 The time course of rooting of microcuttings in relation to auxin dose.

Table II Rooting of single microcuttings of 'Michurinetz' in relation to auxin dose.[1]

IBA (μM)[2]	Mean number of roots per rooted shoot[3]	C.I.[4]
0	3.41 a	± 0.41
0.05	4.12 a	± 0.61
0.50	7.36 b	± 0.99
1.00	7.72 b	± 1.18

[1] Standard microcuttings grown for 16 days on MS medium supplemented with IBA; at 26-28° C; photoperiod 18 hours. 9000 lux.

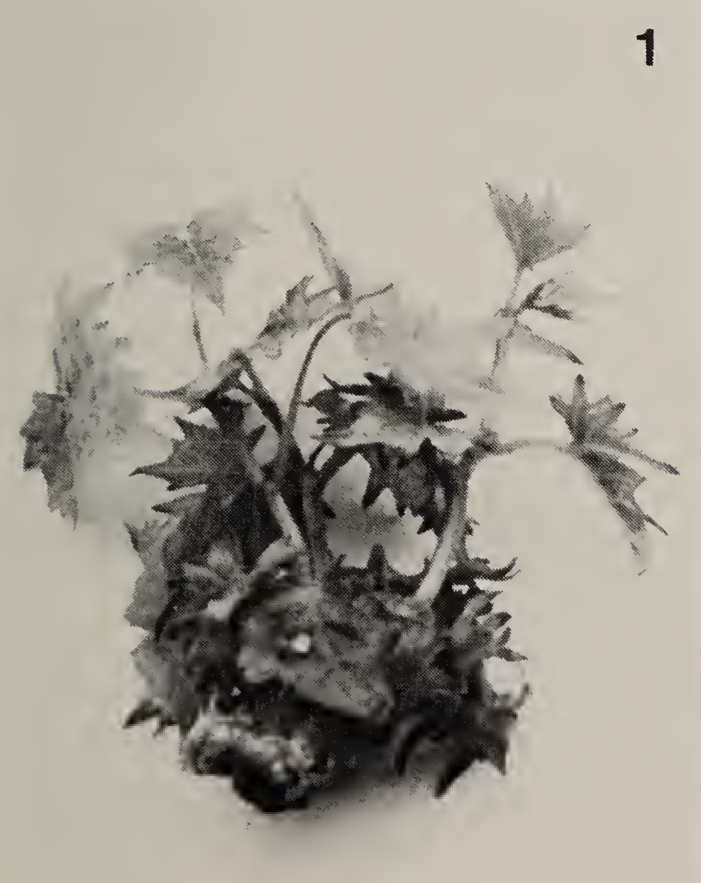
[2] 41-48 replicates per treatment; pooled data from 2 experiments.

[3] Similar letters in a vertical column indicate two means are not significantly different (Student t-test at $P > 0.05$).

[4] 95% Confidence Interval.

Root primordia first appeared at very low frequencies by day 4 (Fig. 3). Over the next 4 days, rooting frequencies increased rapidly on all treatments, with a tendency toward higher frequencies on 2.5 and 5 μM IBA. Final rooting frequencies were high and rather similar, irrespective of IBA dose. Auxin, however, did significantly increase the mean number of roots per shoot at 2.5 and 5.0 μM (Table II). Roots were relatively thick, especially on the auxin treatments (Fig. 2). IBA regularly produced a basal stem callus (in 81-98% of cuttings vs 49% in controls); lateral roots formed in 31-43% of the auxin-treated cultures (vs 4% in controls).

From this work it is clear that 'Michurinetz' can be sustained readily through many passages *in vitro*. Importantly, it is an 'easy-to-root' cultivar. We propose that these data can provide a basis for further testing of this interesting cultivar.



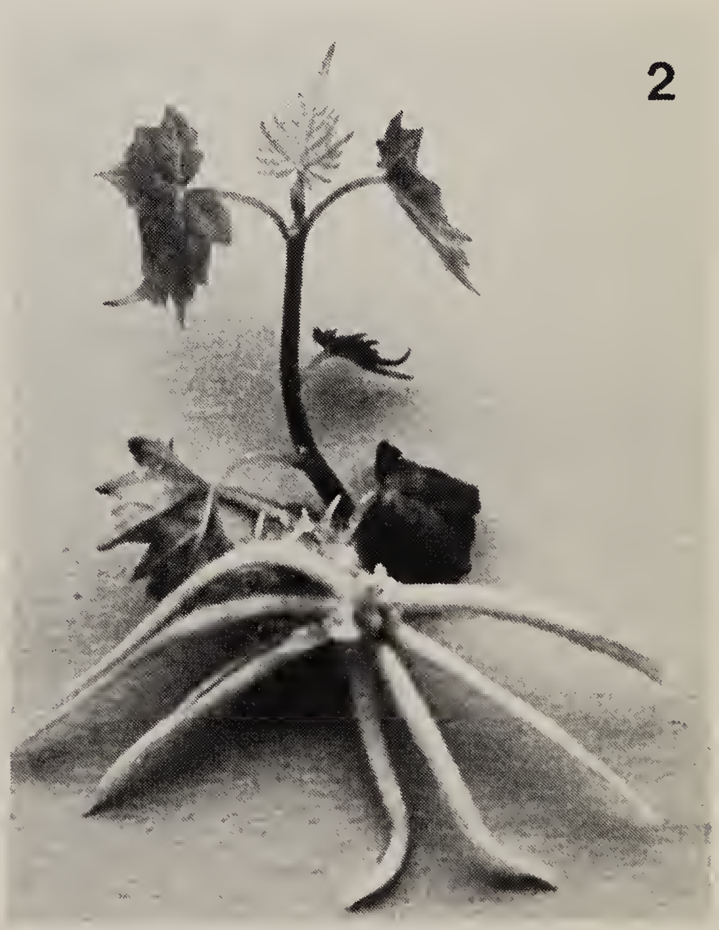


Fig. 1 Stock multiple shoot cultures from 2.5 μM BAP medium.

Fig. 2 Rooted microcutting after treatment with 2.5 μM IBA.

Acknowledgement

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References

Barlass, M., Skene, K.A.M., Woodham, R.C. and **Krake, L.R.** 1982. Regeneration of virus-free grapevines using *in vitro* apical culture. *Ann. Appl. Biol.* 101: 291-295.

Cattell, H. 1984. Nova Scotia: Canada's new wine frontier. *Wine East* 12: 6-23.

Chee, R. and **R.M. Pool.** 1982. The effects of growth substances and photoperiod on the development of shoot apices of *Vitis* cultured *in vitro. Scient. Hortic.* 16: 17-27.

George, E.F. and **Sherrington, P.D.** 1984. Plant Propagation by Tissue Culture. Exegetics Ltd. Hants, England. 709 pages.

Dial, R.L. 1979. Perspectives on winegrowing in Nova Scotia. *Vinifera Winegrowers Jour.* 155: 23-31.

Goussard, P.G. 1982. Morphological responses of shoot apices of grapevine cultured *in vitro. Vitis* 21: 293-298.

Krul, W.R. and **Mowbray, G.H.** 1984. **Grapes. Ch.** 15 *In* Handbook of Plant Tissue Culture Vol. 2. eds. W.R. Sharpe, D.A. Evans, P.V. Ammirato, and Y. Yamada. MacMillan Co. pp. 396-434.

Mantell, S.H., Mathews, J.A. and **McKee, R.A.** 1985. Principles of Plant Biotechnology. Blackwell Scientific Publications, Oxford, 269 pages.

Monette, P. 1983. Influence of size of culture vessel on in vitro prolifieration of grape in a liquid medium. *Plant Cell Tissue Organ Culture* 2: 327-332.

Schreiner, J. 1984/1985. Our wines are getting much, much better. Can. Geogr. 104: 30-39.

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PROCEEDINGS
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Description of Selected Lake Characteristics and Occurrence of Fish Species in T81 Nova Scotia Lakes 63

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DESCRIPTION OF SELECTED LAKE CHARACTERISTICS AND OCCURRENCE OF FISH SPECIES IN 781 NOVA SCOTIA LAKES

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Between 1964 and 1981, the Science Branch of the Department of Fisheries and Oceans, the Canadian Wildlife Service of the Department of the Environment and the Wildlife Division of the Nova Scotia Department of Lands and Forests completed surveys on 781 Nova Scotia lakes. This report identifies the survey locations and provides information on conductivity, pH, surface area, mean and maximum depth and the occurrence of fish species for surveyed lakes. An analysis is provided for the relative frequency of occurrence of selected fish species.

Entre 1964 et 1981, la Section des Sciences du Ministère des Pêches et des Océans, le Service canadien de la faune du Ministère de l'Environnement et la Section de la faune du Département des Terres et des Forêts de la Nouvelle-Écosse ont completé des études sur 781 lacs en Nouvelle-Écosse. Ce rapport identifie les emplacements des lacs et donne des renseignements concernant la conductivité, le pH, la surface, la profondeur moyenne et maximum et les espèces de poissons trouvées dans les lacs étudiés. Une analyse est donnée pour la fréquence relative de quelques espèces de poisson.

Introduction

Surface water in Nova Scotia is essential for production of numerous populations of freshwater dependent fish species. These populations contribute to both commercial and recreational fisheries of significant economic value. A survey of anglers (Cumming 1979) concluded: "In total, during 1974, the sport fishermen of Nova Scotia numbered approximately 188,000, fished 2.2 million days and spent $15.1 million on sportfishing". Most of this fishery was on freshwater. In that same year, the commercial fishery for anadromous alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), Atlantic salmon (*Salmo salar*), rainbow smelt (*Osmerus mordax*), and the catadromous American eel (*Anguilla rostrata*) had a total landed value of $634,000 (J. Cain, pers. comm., Management Branch, Statistic Division, DFO, Scotia-Fundy Region, Halifax, Nova Scotia). The value of these fisheries has undoubtedly increased since 1974.

The aesthetic, non-consumptive value of water and its ecological associations, including all forms of fish and other wildlife, should not be overlooked. These aesthetic values contribute to our social well being. They may be most obvious in settings such as National Parks where they are often interpreted by professional staff for the general public.

Man's activities in recreation, agriculture, forestry, industry in general and other areas may have adverse effects on water quality and quantity, thus affecting the fish, the fisheries and the aesthetics. Consequently, these resources require protection, conservation and in some cases more active management. To accomplish this, resource inventory information is required.

Three agencies that have collected inventory information through lake surveys are: the Science Branch of the Department of Fisheries and Oceans (DFO); the Canadian Wildlife Service (CWS) providing service to Parks Canada; and the Wildlife Division of the Nova Scotia Department of Lands and Forests (L&F). Some of the survey results have been published (Alexander 1972, Beanlands 1980, Ives 1975a, 1975b, Penney and Hiltz 1973, Richard 1977, Richard and Swan 1977, Kerekes 1975, 1982).

This report summarizes data on conductivity, pH, surface area, mean and maximum depth and occurrence of fish species in 781 Nova Scotia lakes surveyed from 1964 to 1981. This information can be of value in fisheries management decisions such as allocation of hatchery-produced trout, protection of unique native species, rejection or approval of introductions of non-native species, or selection of waters for intensive management. These data also provide a baseline for studies on the impact of acid precipitation which has been recognized as a major threat to fish in some areas of Nova Scotia (Farmer et al. 80, Watt et al. 1983). Observations in the report extend

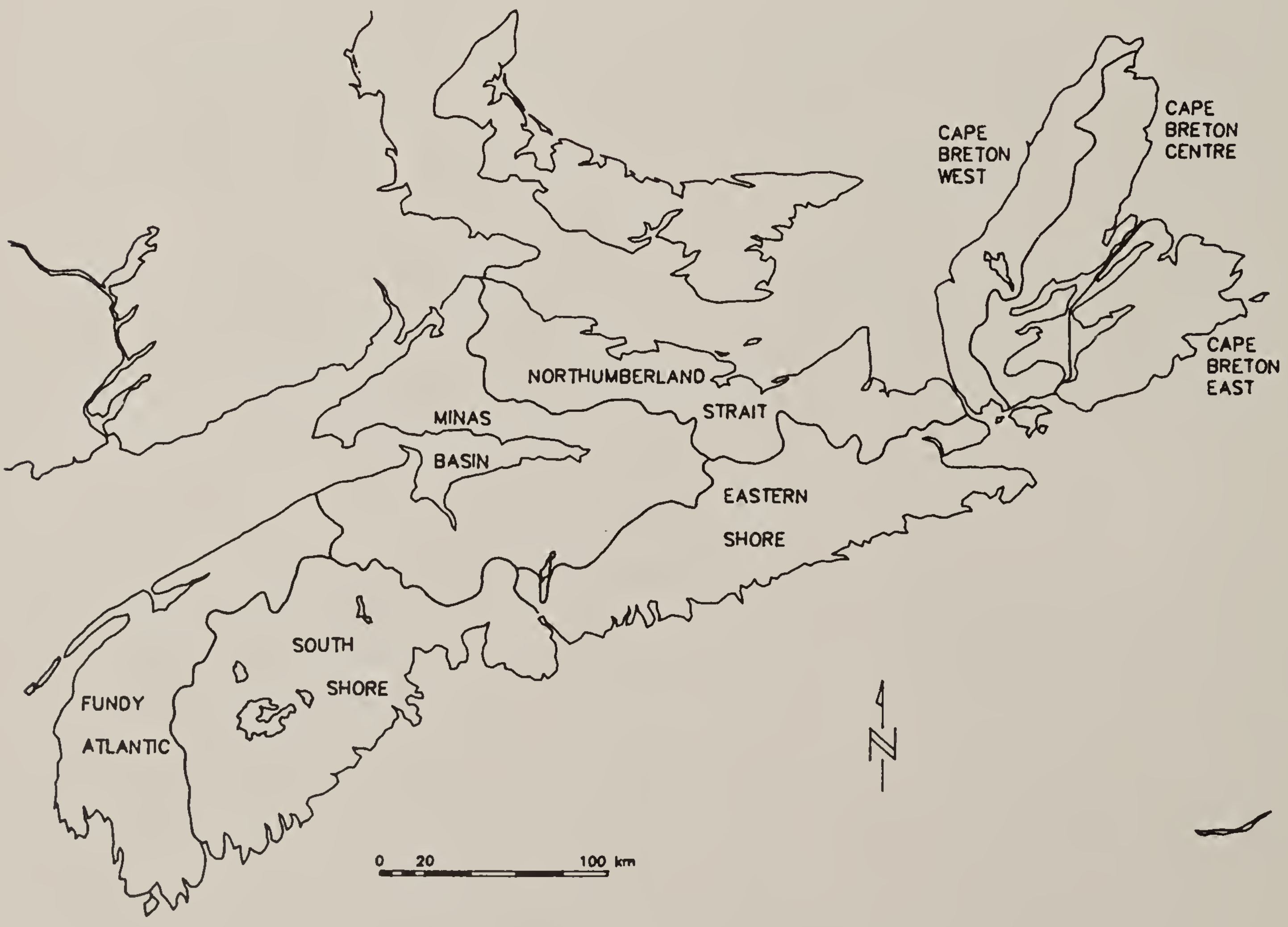

Fig 1 Map of Nova Scotia showing eight major drainage areas used to group surveyed lakes.

the known ranges of a few species and contribute to a better understanding of species distributions and species associations in the province. Publication of these data will hopefully eliminate duplication of the surveys by others.

The report includes only selected information common to most of the surveys. Consequently, some detail such as the distinction between stickleback species is available for some surveys, including most of those conducted by CWS, but is omitted here for the sake of uniformity. Individuals with special interests may wish to contact the author with the appropriate agency (APPENDIX) to verify information or to expand upon information provided.

Methods and Materials

Lake identification

The lake name and geographic co-ordinates, to the nearest minute, at the lake center, are provided as listed in the 1977 volume for Nova Scotia of the Gazetteer of Canada. Where no name was listed, a local name was used or the lake was labelled as "Unnamed" and the co-ordinates were determined using topographic maps (Department of Natural Resources and Energy, 1:50,000 scale) or more detailed maps (NS Dept. of Lands and Forests, Crown Land Forestry Series, 1964, 1:15,840 scale). The Gazetteer and maps were also used to identify lakes by county. When a lake was located on a county line, it was assigned to the county in which the greatest portion of the lake was located. Surveyed lakes were further identified by the watershed in which they were located. In most cases the watershed was taken as the name of the river or lake at the point where water from the surveyed lake flowed to salt water. The watersheds have also been identified using an alpha-numeric code developed by personnel in the Habitat Protection Section, Science Branch, Scotia-Fundy Region of the Department of Fisheries and Oceans (R. Sweeney, pers. comm.). Under this system, each watershed included in this summary can be assigned to one of eight major drainage areas (Fig. 1) as follows: Fundy Atlantic, FA: South Shore, SS; Northumberland Strait, NS; Eastern Shore, ES; Minas Basin, MB; Cape Breton East, CBE; Cape Breton Centre, CBC; Cape Breton West, CBW. Within these major drainage areas, each watershed has been numbered using from one to three digits. The system allows for specific coding of individual lakes, but the full code is not included here.

Survey dates in this report are shown as XXYY, where XX refers to the month (1-12) and YY to the year (64-81). If a lake was surveyed by more than one agency or in more than one year, the results are considered to represent separate surveys and summary information is provided for each.

Physical and chemical characteristics of lakes

Conductivity, measured in μmhos cm^{-1}, from a surface water sample was obtained from most surveys. Measurements were usually made in the field with instruments such as the YSI Model 9-325 conductivity/salinity/temperature meter. Where more than one sample was taken, the average of surface values is reported.

Hydrogen ion concentration was measured for surface water samples. Where more than one value was recorded, the arithmetic mean is reported. Method of pH measurement was usually recorded on survey forms and included chemical field kits (Hach Chemical Co. Inc., Ames, Iowa, USA), various field pH meters and laboratory analysis.

Surface area of lakes was determined using dot grid counts or planimeter measurements, usually on 1:15,840 scale maps or 1:10,000 and 1:15,840 scale aerial photographs, although 1:25,000 and 1:50,000 topographic maps were used for some larger lakes.

Field activities during a typical survey included depth determinations for each lake using echo sounders. Recorded depths were used to produce bathymetric maps with contour intervals of one-meter or greater. These maps are not included in this report, but are available for most surveyed lakes.

Lake volume was taken as the sum of the volumes of all horizontal strata between contours on the bathymetric map. Volume of each stratum was calculated using a planimeter or dot grid to determine area, and by inserting these values in the formula provided by Welch (1948). Mean depth was calculated by dividing volume of the lake by water surface area.

The total number of lakes in the province, by size class, was determined using the 1:50,000 scale Nova Scotia watershed area maps compiled by Maritime Resource Management Services in 1980.

Collection of fish samples

Fish samples were collected by a variety of methods which commonly included gill netting. Gill nets usually consisted of 15.2 m long panels of various mesh sizes between 1.3 cm and 7.6 cm square mesh. Because of the difficulty in properly setting nets in deeper water (>10 m), those areas were likely undersampled. Other sampling methods included trap netting, beach seining, minnow trapping and occasional angling. Not all methods were employed on all lakes surveyed. Methods varied by agency and by year and this was frequently influenced by the personnel involved. Unfortunately, voucher samples for museum storage were not collected from most surveyed lakes except for those in Kejimkujik National Park.

Common and specific names of fishes in this report conform to those listed in the fourth edition of Special Publication No. 12 of the American Fisheries Society (Robins et al. 1980). In order to record the fish species caught in concise tabular form for the APPENDIX, the fish species have been randomly assigned numerical codes as follows:

Scientific Name	Common name	Species code
Catostomus commersoni	white sucker	1
Salvelinus fontinalis	brook trout	2
Morone americana	white perch	3
Perca flavescens	yellow perch	4
Fundulus diaphanus	banded killifish	5
Couesius plumbeus	lake chub	6
Salmo trutta	brown trout	7
Salmo gairdneri	rainbow trout	8
Salmo salar	Atlantic salmon	9
Anquilla rostrata	American eel	10
Salvelinus namaycush	lake trout	11
Notemigonus crysoleucas	golden shiner	12
Notropis cornutus	common shiner	13
Notropis heterolepis	blacknose shiner	14
Gasterosteidae**	sticklebacks	15
Phoxinus eos	northern redbelly dace	16
Osmerus mordax	rainbow smelt	17
*Alosa aestivalis/Alosa pseudoharengus**	blueback herring/alewife	18
Semotilus atromaculatus	creek chub	20
Ictalurus nebulosus	brown bullhead	21
Esox niger	chain pickerel	22
Fundulus heteroclitus	mummichog	23
Pseudopleuronectes americanus	winter flounder	24

Scientific Name	Common name	Species code
Urophycis sp.	hake	25
Coregonus clupeaformis	lake whitefish	26
Micropterus dolomieui	smallmouth bass	27
Morone saxatilis	striped bass	29
Microgadus tomcod	Atlantic tomcod	30
Tautogolabrus adspersus	cunner	31
Peprilus triacanthus	butterfish	32
Myoxocephalus aenaeus	grubby	33
Hemitripterus americanus	Atlantic sea raven	34
Brevoortia tyrannus	Atlantic menhadden	35
Menidia menidia	Atlantic silverside	36
Rhinichthys atratulus	blacknose dace	37

* These two species were not separated.

** Sticklebacks may include four species which were distinguished in some surveys, but not in this summary.

Results and Discussion

Lake location, watershed identification, survey agency, survey date, conductivity, pH, surface area, mean and maximum depth and occurrence of fish species, listed by lake name in alphabetical order and grouped by county, in alphabetical order, is provided in the APPENDIX, for each lake surveyed.

Number of surveys

Some locations were surveyed more than once. In total, the three agencies conducted 826 surveys on 781 lakes (Table I and Table II). This represents 11.7% of the 6,674 Nova Scotia lakes counted as being one hectare or greater in surface area.

Surveys were completed in each county although the Nova Scotia Department of Lands and Forests was the only agency to conduct surveys in all 18 counties (Fig. 2, Table I). The aggregate number completed ranged from 8 surveys in Inverness to 175 in Halifax County. The number of surveys completed may suggest that some counties have been favoured at the expense of others, but that impression ignores the distribution of lakes. If the number of surveyed "named" lakes (APPENDIX) is divided by the number of "named" lakes compiled from the 1961 edition of the Gazeteer of Canada (R.E. Cutting, pers. comm., Science Branch, Freshwater and Anadromous Division, DFO, Scotia-Fundy Region, Halifax, Nova Scotia) and expressed as a percentage (Table I), a survey index reflecting lake distribution is produced. The overall index value of 21% (757 of 3,626 lakes) suggests that surveys have been concentrated on these better known and, therefore, larger lakes. The index by county (Table I) ranges from 7% in Hants (12 of 163) to >100% (25 of 24) in Victoria County. The index for Inverness is above average at 32% (8 of 25) while the 170 "named" lakes surveyed in Halifax County represent only 14% (170 of 1,240) and is, therefore, below average. The number of surveys completed and the survey index could be used to determine the priority for location of future surveys although, in reality, surveys are frequently conducted in response to a site specific request for information.

Surface area

Total surface area of surveyed lakes is 69,287 ha or 30.7% of the surface area calculated (225,495 ha) for all lakes in the province. Although the percentage of completed surveys increases with increasing lake size (Table II), not all of the largest lakes have been surveyed. Emphasis has been placed on lakes in the 10 to 100 hectare

Table I Number of surveys completed by the Department of Fisheries and Oceans, Nova Scotia Lands and Forests, and the Canadian Wildlife Service in each county and in the aggregate (excluding duplicate surveys).

County	DFO	L&F	CWS	Aggregate	Named lakes* surveyed	Named lakes in gazetteer	Survey† index (%)
Annapolis	0	48	6	53	50	129	39
Antigonish	10	7	0	15	13	28	46
Cape Breton	14	21	12	46	46	211	22
Colchester	0	19	0	19	19	85	22
Cumberland	0	28	1	25	25	58	43
Digby	6	17	6	25	25	229	11
Guysborough	39	60	0	98	93	450	21
Halifax	41	135	0	175	170	1,240	14
Hants	2	11	0	12	12	163	7
Inverness	0	7	1	8	8	25	32
Kings	0	50	0	43	43	84	51
Lunenburg	5	34	0	39	39	281	14
Pictou	1	33	0	33	29	81	36
Queens	14	28	32	61	61	185	33
Richmond	0	13	0	13	12	64	19
Shelburne	0	38	0	38	35	108	32
Victoria	0	8	19	26	25*	24	100
Yarmouth	14	46	0	52	52	181	29
Total	146	603	77	781 lakes	757	3,626	21
Grand Total		826 surveys					

* Some lake names in the APPENDIX have not been gazetted. Named lakes surveyed may therefore exceed the number of named lakes in Gazetteer.

† The number of named lakes surveyed, expressed as a percentage of the gazetted named lakes in the county, serves as an index to the survey distribution.

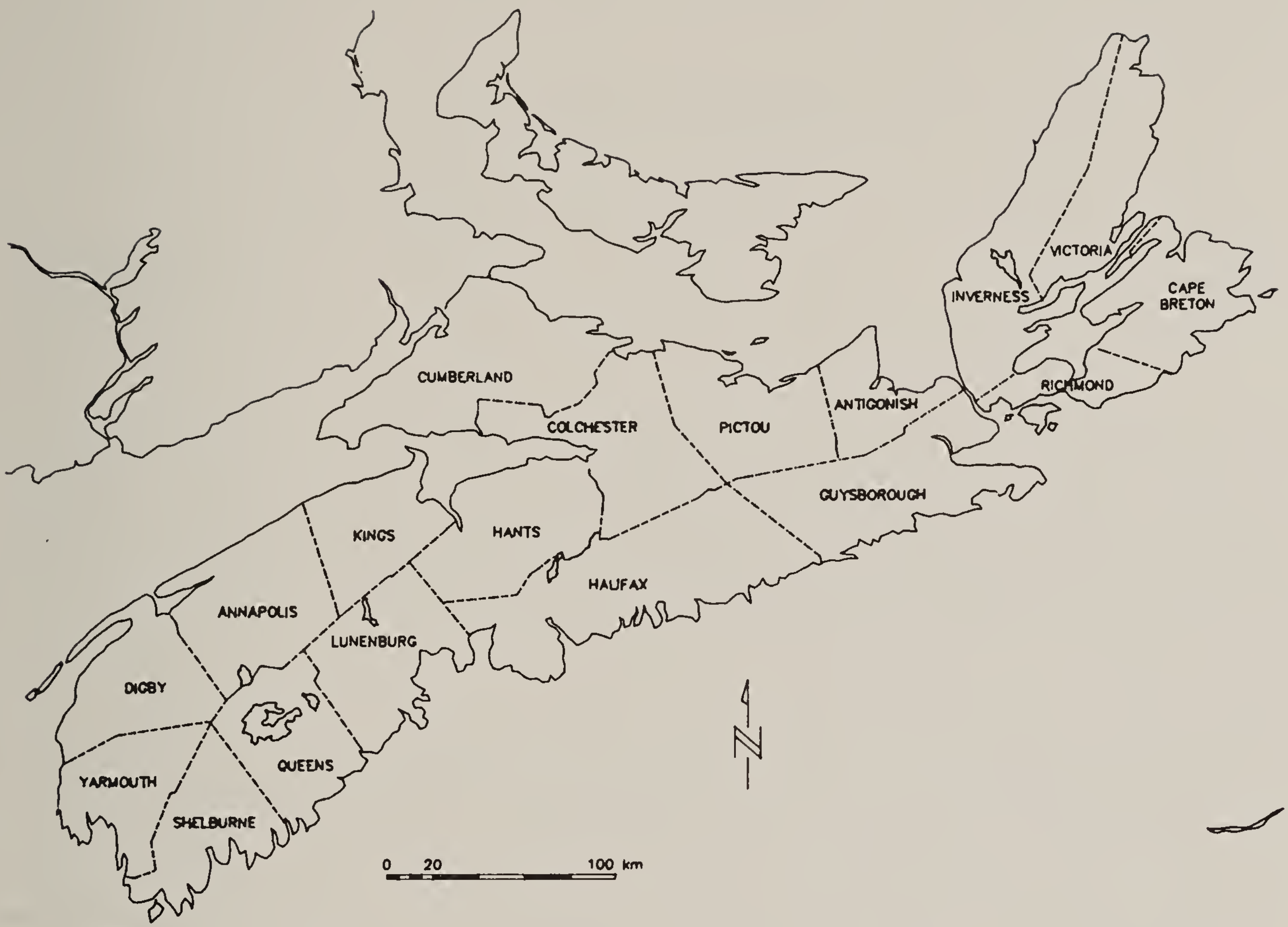

Fig 2 Map of Nova Scotia showing county lines.

size (57% of all surveys). Lakes of this size were best suited to the equipment, methods, personnel and time available. Mean surface area for all surveyed lakes is 89 ha (Table III), but the large standard deviation (279 ha) indicates the great variability. One lake with a surface area of less than one ha was surveyed in Cape Breton County, but size ranged to a maximum of 5,736 ha for Lake Ainslie in Inverness County. Mean surface area of all 6,674 lakes in the province was estimated at 34 ha. Again, the difference in mean surface areas for all lakes and for all surveyed lakes indicates a selection of larger lakes for survey.

Conductivity

Conductivity values were generally low and showed little variation between locations. However, some extreme high values such as 20,000 μmhos cm^{-1} for Upper and Lower Redhead Pond in Victoria County, or 15,100 in Oyster Pond and 12,700 in Harpell Pond, both in Halifax County, and others, were recorded but were almost certainly the result of seawater mixing. A total of 17 such sites were identified and these values were not included in the calculation of mean conductivity for lakes in the province. The maximum value that was included was 12,400 μmhos cm^{-1} for Park Lake, Cumberland County. This high value can be attributed to gypsum and salt deposits in that area (Roland 1982). Mean conductivity by county ranged from 26.4 μmhos cm^{-1} for Lunenburg to 656.8 for Cumberland (Table III). Mean and standard deviation for the province was 69.5 ± 493.0 μmhos cm^{-1}. However, the mean ($n = 637$) drops to 50.1 when the value for Park Lake is excluded. Even this value is probably biased upward by wind carried sea spray. Some lakes in the survey are also known to be influenced by road salts and sewage loading which may increase conductivity.

Table II Number of lakes and number of surveyed lakes in Nova Scotia in each of seven selected size categories.

	Surface area (ha)		
	1.0-2.0	2.1-5.0	5.1-10.0
Number	1,339	1,436	1,163
Number surveyed	9	60	119
% Surveyed	1	4	10

Low conductivity is directly related to low levels of total dissolved solids in Nova Scotia lakes (Hayes 1963, Kerekes 1973, Kerekes et al. 1982), and since low levels of dissolved solids are associated with low fish production (Ryder 1965, Ryder et al. 1974), it is not surprising that lakes in the region have been classified as relatively unproductive (Alexander 1975, Alexander and Merril 1976).

Depth

Maximum depth values were available for 772 surveyed lakes (Table III) and ranged from 0.4 m for one lake in Cape Breton County to 52.4 m recorded for Lochaber Lake in Antigonish County. Martin and Olver (1976) have shown that almost 75% of the lakes known to support lake trout (*Salvelinus namaycush*) in Ontario have a maximum depth in the 15.2 - 45.7 m range. Since our mean of maximum lake depths recorded is only 8.2 m (Table III), it is not surprising that this species is reported from only a few lakes in the province even though it was introduced extensively from hatcheries in the early 1900's.

Mean depth of all lakes by county ranged from 1.4 m for Colchester to 4.8 m for Hants (Table III). Mean depth of all 660 lakes was only 2.8 m. This combination of shallow depth and low nutrient levels suggests the potential of using lake fertilization as a management tool where flushing rates are low.

Acidity

Some pH determinations from these lake surveys were considered to be highly reliable and have been recorded in the National Water Quality Data Bank (NAQUADAT) but, in other cases, measurements were less precise. Values for 730 lakes examined ranged from 4.0 to 9.7. Although specific pH values, and extreme values in particular, may be questionable, average values probably vary as a result of differing geology. Mean pH by county (Table III) ranged from 5.5 in Shelburne to 7.4 in Inverness. Average pH for all sites was 6.2.

Portions of Atlantic Canada have been shown to be highly susceptible to the effects of acid precipitation since the geology of the region provides little buffering capacity. In Nova Scotia, the Southwestern mainland, parts of the Eastern Shore and the highlands of Cape Breton have been shown to be sensitive (Clair et al. 1982). Impacts on fisheries have been noted in some areas (Watt et al. 1983). Apparently, the eight sites surveyed in Inverness were not in sensitive areas or were not yet seriously affected by acid precipitation. The pH values given in this report may become useful reference points to evaluate the impact of acid precipitation.

Fish species

Of the 781 surveyed lakes, 744 were sampled to obtain information on their fish populations. A few lakes were intensively studied to provide information on factors such as fish abundance and age and growth, but review of those data is beyond the

Table II continued

	Surface area (ha)				
	10.1-25.0	25.1-100.0	100.1-500.0	500.1+	Total
Number	1,249	1,081	367	39	6,674
Number surveyed	196	249	129	19	781
% Surveyed	16	23	35	49	12

scope of this report. The presence of individual fish species was selected as usually reliable information common to most surveys and is included here (APPENDIX). Where an extension of the range in distribution of a species is implied, it would be desirable to confirm the presence of that species in that location and to provide specimens for museum storage. In view of the methods employed and the short time allocated to fish collections, it is probable that some fish species were occasionally missed during sampling. Consequently, the occurrence of most or all fish species is under-represented in the survey results. Furthermore, the degree to which occurrence is under-reported is likely to be variable since vulnerability to capture would vary by species and by capture method. Sampling effort by gear-type would also vary between surveys depending on both the gear preference and capabilities of the survey crews.

With the limitations noted above, the fish occurrence information has been summarized by species and by county. Where a lake was sampled more than once, only the most recent information was used rather than combining years. The results (Table IV) show some interesting trends worth note and comment.

Fishless lakes

No fish were caught in 34 (5%) of the 744 surveyed lakes. In a few cases, these may be truely "fishless" lakes, but in many cases the absence of fish specimens probably reflects sampling difficulties, possibly in combination with low fish abundance.

Anguilla rostrata. American eel were caught in 112 lakes (15%), but are difficult to catch in gill nets because of their body shape. Although they are catadromous, eels are often present in freshwater upstream from obstacles which would constitute a barrier to the migration of other fish species. In fact, in two lakes on the highlands of Cape Breton, eels were the only fish present. American eels were probably present in almost all lakes including many of those that appeared to be "fishless".

Alosa aestivalis/Alosa pseudoharengus. Blueback herring and/or alewife were recorded from 84 locations (11%), but because of the large numbers sometimes encountered and the difficulty in removing them from gill nets, survey crews often avoided setting nets at times or in places where they were most likely to be captured. No distinction was made between the two species. Both species may have been present in the lakes although our observations suggest that blueback spawn in flowing streams near seawater while alewives migrate to spawn in freshwater lakes. Alewives can become landlocked, but no landlocked populations have been identified in Nova Scotia. The presence of either of these species in any location is, therefore, considered to be evidence of clear access to that location from the sea. These species make little contribution to the sport fishery although post-spawners take readily on flies. Juveniles are important as a forage species and adults on the spawning migration support important commercial fisheries which have come under study in recent years (Alexander 1984, Alexander and Vromans 1984, 1985, 1986, Crawford 1983).

Table III Mean surface area, conductivity, depth (maximum and mean) and acidity for surveyed Nova Scotia lakes.

					Depth (m)					
	Surface area (ha)		Conductivity (μmho cm^{-1})		Maximum		Mean		Acidity (pH)	
County	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
Annapolis	53	87 ± 111	46	32.5 ± 7.6	53	6.4 ± 3.2	53	2.3 ± 0.8	47	6.2 ± 0.5
Antigonish	15	46 ± 79	15	87.0 ± 85.8	14	11.8 ± 13.1	15	4.6 ± 5.4	15	6.9 ± 0.9
Cape Breton	46	47 ± 75	38	75.9 ± 101.1	43	6.4 ± 7.0	43	2.4 ± 2.2	46	6.5 ± 0.8
Colchester	19	25 ± 41	16	27.3 ± 16.1	19	6.6 ± 5.2	6	1.4 ± 0.6	19	6.5 ± 0.6
Cumberland	25	43 ± 41	21	656.8 ± 2,692.4	25	9.7 ± 8.9	5	1.8 ± 1.2	25	7.0 ± 0.5
Digby	25	66 ± 78	15	43.3 ± 11.6	23	6.2 ± 3.5	23	2.4 ± 1.2	16	5.7 ± 1.0
Guysborough	98	39 ± 57	91	37.8 ± 30.9	98	7.4 ± 5.3	90	2.6 ± 1.9	96	6.2 ± 0.5
Halifax	175	85 ± 192	159	58.0 ± 74.8	175	10.6 ± 8.4	118	3.1 ± 2.4	167	6.2 ± 0.6
Hants	12	96 ± 79	11	79.2 ± 118.5	12	13.5 ± 10.4	11	4.8 ± 2.8	9	6.3 ± 0.7
Inverness	8	744 ± 2,017	6	171.7 ± 129.0	8	12.4 ± 8.5	7	4.6 ± 2.4	8	7.4 ± 0.7
Kings	43	91 ± 144	36	31.3 ± 4.6	41	6.8 ± 4.0	43	2.5 ± 1.2	40	6.4 ± 0.5
Lunenburg	39	94 ± 190	24	26.4 ± 5.2	38	9.0 ± 8.6	36	3.7 ± 3.3	30	6.8 ± 0.6
Pictou	33	59 ± 138	23	43.8 ± 36.5	33	5.3 ± 4.0	28	2.5 ± 1.8	32	6.8 ± 0.8
Queens	61	149 ± 362	36	27.0 ± 5.7	61	7.0 ± 4.4	59	2.7 ± 1.3	60	5.7 ± 0.7
Richmond	13	107 ± 184	7	57.7 ± 23.8	12	10.3 ± 5.6	12	3.6 ± 2.0	12	6.5 ± 0.3
Shelburne	38	90 ± 73	32	32.5 ± 5.9	38	6.2 ± 5.6	36	2.1 ± 1.4	37	5.5 ± 0.7
Victoria	26	23 ± 25	21	39.3 ± 29.8	26	7.3 ± 7.0	26	2.8 ± 3.3	26	6.3 ± 1.0
Yarmouth	52	110 ± 253	42	76.8 ± 90.9	52	8.2 ± 5.3	49	2.7 ± 1.2	45	6.2 ± 0.9
TOTAL	781	89 ± 279	638	69.5 ± 493.0	772	8.2 ± 6.8	660	2.8 ± 2.1	730	6.2 ± 0.8

N = Number of values used in calculation of mean.
± = Standard deviation.

Table IV Number of Nova Scotia lakes, grouped by county, in which the most common fish species were captured during surveys.

	Ann.	Ant.	C.B.	Col.	Cum.	Dig.	Guy.	Hal.	Han.	Inv.	Kin.	Lun.	Pic.	Que.	Ric.	She.	Vic.	Yar.	
Lakes Fished (n)	47	15	43	17	25	20	96	170	11	8	41	33	33	58	12	38	26	51	744
Anquilla rostrata	8	4	7	0	2	2	11	33	2	1	7	1	3	19	0	3	5	4	112
Alosa aestivalis/Alosa pseudoharengus	0	2	3	0	1	1	20	26	0	3	0	3	6	2	2	1	4	10	84
Coregonus clupeaformis	3	0	0	0	0	0	2	1	0	0	0	1	1	5	0	0	0	0	13
Salmo gairdneri	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	4
Salmo salar	0	0	0	0	1	1	2	1	0	0	0	2	2	0	1	0	0	2	12
Salmo trutta	2	3	0	0	1	0	4	0	0	0	0	0	0	3	1	0	0	0	14
Salvelinus fontinalis	18	10	27	14	10	11	65	97	4	5	20	16	20	29	8	14	20	14	402
Osmerus mordax	0	2	0	0	1	0	3	1	0	2	0	0	1	0	2	0	3	0	12
Couesius plumbeus	0	0	0	0	1	0	3	8	4	0	6	8	1	1	2	0	0	0	34
Notemigonus crysoleucas	28	4	7	0	13	5	28	58	4	1	21	18	13	28	3	17	1	15	264
Notropis cornutus	0	0	0	1	2	0	8	4	0	0	1	3	0	0	0	0	0	0	17
Phoxinus eos	0	0	0	0	2	0	0	2	0	1	0	0	1	0	2	0	0	0	8
Semotilus atromaculatus	3	0	0	0	2	1	1	1	0	0	3	3	0	1	0	0	0	1	16
Catostomus commersoni	34	11	11	2	15	10	65	97	11	5	31	26	20	35	2	8	1	25	409
Ictalurus nebulosus	33	2	3	2	7	13	20	41	3	0	36	18	2	38	0	23	0	31	272
Fundulus diaphanus	31	4	8	8	12	5	28	50	5	4	18	8	7	30	8	9	2	7	244
Fundulus heteroclitus	0	0	0	0	1	0	0	1	0	0	0	0	3	0	0	0	3	2	10
Gasterosteidae[1]	0	1	9	5	5	2	26	14	2	3	7	3	6	2	3	1	1	0	90
Morone americana	15	8	14	1	14	9	19	49	1	3	3	8	7	31	6	6	4	37	235
Micropterus dolomieui	0	0	0	0	0	1	0	7	0	0	1	1	0	0	0	0	0	1	11
Perca flavescens	37	7	0	2	9	11	28	35	5	0	22	21	13	45	0	33	0	35	303
Fishless lakes	1	0	8	0	0	1	2	17	0	0	0	2	0	0	0	0	2	1	34

Abbreviations: Ann., Annapolis; Ant., Antigonish; C.B., Cape Breton, Col., Colchester; Cum., Cumberland; Dig., Digby; Guy., Guysborough; Hal., Halifax; Han., Hants; Inv., Inverness; Kin., Kings; Lun., Lunenburg; Pic., Pictou; Que., Queens; Ric., Richmond; She., Shelbourne; Vic., Victoria; Yar., Yarmouth.

[1] May include four species.

Coregonus canadensis. The Acadian whitefish is unique to Nova Scotia. Although it was not caught during surveys, its presence was recently confirmed in three lakes near Bridgewater in Lunenburg County with evidence for a marginal population in the Annis River, Yarmouth County (Edge 1984). A population in the Tusket River appears to have been extirpated by acid rain (McAllister et al. 1985). This species is classified as endangered and regulations prohibit its harvest.

Coregonus clupeaformis. Lake whitefish were caught in 13 surveyed lakes. Since this species is known to have been reared in the hatchery program and distributed to many locations in the province, it is not known whether existing populations are native or introduced. Specimens collected from a survey of Pringle Lake (45°22′N; 61°57′W), Guysborough County in 1973 were submitted to the Royal Ontario Museum for identification because of the potential for confusion with Acadian whitefish. These specimens were confirmed to be lake whitefish (W.B. Scott, pers. comm., retired, St. Andrews, New Brunswick) and at that time represented the easternmost record for the species in Nova Scotia. The species has since been recorded from the Mira River, Cape Breton (J. Gilhen, pers. comm., Nova Scotia Museum, Halifax, Nova Scotia). Lake whitefish in Nova Scotia are seldom caught by anglers. Because of their deep water habits, it is likely that they are under-represented in this survey.

Salmo gairdneri. Rainbow trout were reported from only four surveyed lakes even though the species has been released to numerous locations since the original introduction through the hatchery program in 1899. Some populations have been maintained through annual distributions, often in "put-and-take" recreational fisheries. In addition, rainbow trout have been increasingly reared in the growing aquaculture program over the past decade. The escape of rainbow trout from the Cape Breton Development Corporation's aquaculture facilities to the Bras D'Or Lakes has been sufficient to establish a popular recreational fishery. There is evidence (Sabean 1983) that this population is now reproducing naturally. Rainbow trout will likely continue to be used in aquaculture and the high demand for a recreational fishery may lead to expansion of put-and-take fisheries and possibly to renewed efforts to establish self-sustaining populations.

Salmo salar. Atlantic salmon were recorded from only 12 surveyed lakes, but survey crews would make a conscious effort to avoid their capture because of the high public profile of the species. Most specimens captured were juveniles, probably from anadromous populations, although landlocked Atlantic salmon occur in Lake Charles and Grand Lake (44°55′N; 63°36′W), in the Shubenacadie watershed and probably in other watersheds.

Salmo trutta. The brown trout was first introduced to Nova Scotia through the hatchery program in 1925. Historical records of the Department of Fisheries and Oceans show distributions to all counties except Hants, Inverness, Richmond and Victoria. Current survey results show brown trout to be present in only 14 of the surveyed lakes in six counties. Because brown trout are difficult to catch, they are probably under-represented here. It is interesting to note that the species was recorded from Long Lake, Richmond county even though none were officially released there. This suggests unofficial introductions, natural colonization or incomplete records. Brown trout distributions from hatcheries were discontinued in 1969 because of low angler acceptance, the potential for undesirable competition between brown trout and native brook trout and because of poor production results in the hatcheries. There is a growing public demand to continue rearing this species (M. Hill, pers. comm., Nova Scotia Department of Fisheries, Pictou, Nova Scotia).

Salvelinus fontinalis. The brook trout was second only to the white sucker (*Catostomus commersoni*) in frequency of occurrence being reported in 402 (54%) surveys. This species was also found in lakes of all counties although the number caught was frequently small. The brook trout is the species most preferred by anglers in Nova Scotia (Cumming 1979) and has been the focus of much work on inland fisheries management in the province. Historically, this management activity has been largely limited to distribution of hatchery-produced fish. Since it was initiated in 1873, however, the program has gone through an evolutionary process which started with the distribution of millions of fish annually, but has tended toward the distribution of fewer but larger fish in recent years. Some stocking has now been identified as purely put-and-take while maintenance stocking with fall fingerlings has been advocated on the broader scale. The effectiveness of this stocking program may be improved through judicious selection of the most suitable lakes based on inventory data.

Salvelinus namaycush. Lake trout were captured only in Sherbrook Lake (Nine Mile Lake), Lunenburg County, but probably occur in Dollar Lake, Halifax County (R. Semple, pers. comm., Science Branch, Freshwater and Anadromous Division, DFO, Scotia-Fundy Region, Halifax, Nova Scotia) and perhaps others. Collections in the Nova Scotia Museum include specimens from Pockwock Lake and Dollar Lake, Halifax County and Nine Mile Lake (Sherbrooke Lake), Lunenburg County (Gilhen 1974). As with lake whitefish, this species is known to have been reared in the hatchery program and distributed to many locations in the province although records of occurrence of this species pre-date any hatchery introductions. It is not known whether existing populations are native or introduced. It appears that the hatchery distributions were not highly successful in establishing self-sustaining populations of lake trout. However, in view of the morphometric characteristics of these lakes, as previously discussed, this failure is not surprising. Lake trout are currently unimportant in the recreational fishery.

Osmerus mordax. Rainbow smelt were caught in 12 surveyed lakes, but they are difficult to capture and may be more common. Some smelt populations are believed to be landlocked in Nova Scotia, but most are anadromous. Rainbow smelt support a hook and line recreational ice fishery in several brackish water locations such as Porter's Lake, Halifax County, and in some freshwater locations where the legality of the fishery is questionable under current regulations. Rainbow smelt also support a fall and winter commercial box-net fishery and a spring dip-net fishery which could be classed as recreational or subsistence commercial.

Esox niger. Chain pickerel were caught in nine of the surveyed lakes. Distribution was limited to four watersheds, all in Yarmouth County. These are all believed to be introduced populations. This species also occurs in Digby County where it was illegally introduced to the Spectacle Lake system in about the 1940's (Gilhen 1974). Chain pickerel are seldom sought by anglers in Nova Scotia, and there is concern that they could displace populations of native trout and/or salmon.

Notemigonus crysoleucas. Golden shiner were reported from 264 (35%) lakes and in all 18 counties. The species is not harvested in the sport fishery but is used as bait. Use of this or other species as bait has probably contributed to unintentional introductions.

Catostomus commersoni. The white sucker was caught most frequently, occurring in 409 (55%) surveyed lakes. This species was found in all counties, but is seldom sought by anglers.

Ictalurus nebulosus. Brown bullhead were caught in 272 (37%) lakes, but were absent from surveyed lakes in three of the four counties of Cape Breton Island.

Fundulus diaphanus. Banded killifish were reported from 244 surveyed lakes (33%) and in all counties. Because of the survey methods used, it is likely that this species is highly under-represented. Banded killifish are frequently used as bait in the recreational fishery.

Fundulus heteroclitus. The mummichog is considered to be very common in Nova Scotia, but because it is usually found only in salt or brackish water, the species was recorded from only ten of the surveyed lakes. This species is also used extensively as bait in the recreational fishery.

Gasterosteidae. Sticklebacks were identified to species in some but not all surveys. In this summary, no distinction is made between the four species of stickleback (*Apeltes quadracus, Culaea inconstans, Gasterosteus aculeatus,* and *Pungitius pungitius*) which may have been present. Sticklebacks occurred in 90 lakes (12%), but because of their small size, the presence of these species is probably under-represented.

Morone americana. White perch were captured in 235 lakes (32%) and in all counties. Gilhen (1974) reports that in some locations they may reach a length of 38 cm and 1.4 kg. White perch may be found in either fresh or saltwater although they are not saltwater dependent. This is the preferred species of very few anglers, but they do contribute to the recreational fishery. Anglers frequently mistake them for smallmouth bass (*Micropterus dolomieui*).

Morone saxatilis. Striped bass were caught only in Lake Clear, Annapolis County. However, because this species is anadromous and spawns in streams, few would be expected during lake sampling. Striped bass contribute to the commercial fishery in some estuaries and to prize sport fisheries such as that of the Annapolis River (Jessop and Doubleday 1976) although the future of that fishery is in jeopardy because of reproductive failure from 1972 to 1978 (Jessop 1980).

Micropterus dolomieui. Smallmouth bass were captured in 11 lakes. Historical records of the Department of Fisheries and Oceans show that this species was introduced to the province in Bunker Lake, Yarmouth County, in 1942. Introductions were subsequently made to lakes in at least half the counties of the mainland. Naturally reproducing populations of smallmouth bass are now well established in many locations although they are absent from Cape Breton Island. Smallmouth bass from Nova Scotia tend to be small with an average size of 27.7 cm recorded for creeled fish in Kings County in 1982 (Sabean 1984). This has detracted from their popularity in the sport fishery although personal observations suggest that popularity has increased since about the mid-1970's. As expected, public requests for introduction of smallmouth bass have increased accordingly. There is concern that the species can displace populations of native sport fish.

Perca flavescens. Yellow perch were captured in 303 lakes (41%), but were notably absent from the 89 lakes fished in the four counties on Cape Breton Island. Even though the occurrence of most species is under-represented, it is unlikely that yellow perch are present on Cape Breton. Although yellow perch occur often and in relatively large numbers, individual size is generally small. This small size could be a reflection of environmental variables, but may be largely a result of genetic factors currently under study (G.E. Newsome, pers. comm., Department of Biology, St. Francis Xavier University, Antigonish, Nova Scotia).

Cyprinidae. With the exception of the golden shiner, minnows were caught infrequently during the lake surveys. Since most of the minnow species do not grow to sizes commonly vulnerable to gill nets, they are considered to be under-represented in this summary. These species include: lake chub (*Couesius plumbeus*), common shiner (*Notropis cornutus*), blacknose shiner (*Notropis heterolepis*), northern redbelly dace (*Phoxinus eos*), blacknose dace (*Rhinichthys atratulus*) and creek chub (*Semotilus atromaculatus*). Minnows are frequently caught by anglers for use as bait in the sport fishery, but to date, commercial captures have been too insignificant to require imposition of a harvest policy such as that recently reviewed for Ontario (Anonymous MS 1981).

Marine Species

Nine species of fish which occurred infrequently during the surveys can be regarded as marine species which were present in brackish water of some lakes. These species are: Atlantic menhaden (*Brevoortia tyrannus*), Atlantic tomcod (*Microgadus tomcod*), hake (*Urophycis* sp.), Atlantic silverside (*Menidia menidia*), cunner (*Tautogolabrus adspersus*), butterfish (*Peprilus triacanthus*), Atlantic sea raven (*Hemitripterus americanus*), grubby (*Myoxocephalus aenaeus*) and winter flounder (*Pseudopleuronectes americanus*).

Species associations

In addition to observations on the peculiarities of distribution of each fish species, the association of these species was examined by comparing the frequency of occurrence (expressed as a percentage of the surveyed lakes) of selected fish species in each county, through regression analysis. American eel, brook trout, golden shiner, white sucker, brown bullhead, banded killifish, stickleback, white perch and yellow perch were included in this comparison. The results show some interesting trends (Table V).

There was no significant correlation between the occurrence of white perch, banded killifish and American eel and the occurrence of any other fish species. This probably reflects a tolerance by these species to a wide range of environmental factors. In the case of American eel, the species distribution is considered to be almost ubiquitous even though it was caught in only 15 percent of the surveyed lakes. Failure to show a correlation between the random capture of American eel and any other species therefore is to be expected.

There was a negative correlation between the occurrence of brook trout and all other species except stickleback. This correlation was significant for white sucker and was highly significant for brown bullhead, golden shiner and yellow perch. The positive correlation with stickleback was also significant. The occurrence of stickleback showed a significant negative correlation with brown bullhead and a highly significant negative correlation with yellow perch. Highly significant positive correlations were also shown between the occurrence of: golden shiner and brown bullhead; golden shiner and white sucker; golden shiner and yellow perch; and brown bullhead and yellow perch.

Positive correlations such as that between brook trout and stickleback probably indicate a preference by the two species for similar environmental conditions. Negative correlations such as that between brook trout and yellow perch probably indicate a preference by the two species for dissimilar environmental conditions although it could also indicate species interactions detrimental to the success of one of the two species. These species interactions are known to influence growth and survival of planted salmonids (Fraser 1972, 1978a, 1978b, 1981).

Survey results of the type provided here are increasingly important to the selection of waters for future fisheries management. This will include more selective use of hatchery reared fish, but may be expanded to include more restrictive regulations or other management techniques.

Acknowledgement

Numerous individuals participated in the lake surveys although the majority were under the supervision of Ms. J. Costelo with L&F. Surveys by DFO were completed by personnel working in the Scotia-Fundy Region and later summarized by staff of the Gulf Region. The efforts and interest of summer student Francine Poitras are particularly noteworthy. Drs. R. Randall and M. Chadwick with the Science Branch, Gulf Region, reviewed draft manuscripts of the report and provided valuable comment for improvement.

Table V Correlation coefficients from regression analysis of frequency of occurrence of selected fish species in Nova Scotia lake surveys.

Species	*Salvelinus fontinalis*	*Notemigonus crysoleucas*	*Catostomus commersoni*
Anquilla rostrata	-0.059	0.148	0.336
Salvelinus fontinalis		-0.724**	-0.477*
Notemigonus crysoleucas			0.607**
Catostomus commersoni			
Ictalurus nebulosus			
Fundulus diaphanus			
Gasterosteidae[1]			
Morone americana			

[1] May include four species.
* Indicates significance at 95% confidence limit.
** Indicates significance at 99% confidence limit.

References

Alexander, D.R. 1972. Halifax-Dartmouth area lake surveys, 1971. Resource Development Branch, Fisheries Service, Halifax, Nova Scotia. *Manuscript Report No. 72-16, 154 p.*

Alexander, D.R. 1975. Sport fisheries potential on twenty lakes in the headwaters of the Shubenacadie River System, Nova Scotia. Resource Development Branch, Fisheries and Marine Service. *Technical Report Series No. MAR/T-75-10, 16 p.*

Alexander, D.R. 1984. Status of the Margaree River gaspereau fishery (1983). Department of Fisheries and Oceans, Fisheries Research Branch, P.O. Box 5030, Moncton, N.B. *CAFSAC Research Document 84/17. 14 p.*

Alexander, D.R., and **Merrill, S.P.** 1976. The unexploited brook trout population of Big Indian Lake, Nova Scotia - Vital statistics and potential fisheries. Resource Branch, Fisheries and Marine Service. *Technical Report Series No. MAR/T-76-4, 19 p.*

Alexander, D.R., and **Vromans, A.H.** 1984. Status of the Miramichi estuary gaspereau fishery (1983). Department of Fisheries and Oceans, Fisheries Research Branch, P.O. Box 5030, Moncton, N.B. *CAFSAC Research Document 84/23. 23 p.*

Alexander, D.R., and **Vromans, A.H.** 1985. Status of the Margaree River gaspereau fishery (1984). Department of Fisheries and Oceans, Fisheries Research Branch, P.O. Box 5030, Moncton, N.B. *CAFSAC Research Document 85/91. 17 p.*

Alexander, D.R., and **Vromans, A.H.** 1986. Status of the Margaree River gaspereau fishery (1985). Department of Fisheries and Oceans, Fisheries Research Branch, P.O. Box 5030, Moncton, N.B. *CAFSAC Research Document 86/31. 17 p.*

Anonymous MS 1981. *A baitfish harvest policy for Ontario.* Report of S.P.O.F. Working Group No. 11. Ontario Ministry of Natural Resources, 30 p.

Beanlands, D.I. 1980. Surveys of ten lakes in Guysborough, Halifax, Hants and Lunenburg counties, Nova Scotia, 1978. *Can. Data Rep. Fish. Aquat. Sci. No. 192, v + 31 p.*

Clair, T.A., Witteman, J.P., and **Whitlow, S.H.** 1982. Acid precipitation sensitivity of Canada's Atlantic provinces. Environment Canada, Inland Waters Directorate, Atlantic Region, Water Quality Branch, Moncton, New Brunswick. *Technical Bulletin No. 124, v + 12 p.*

Crawford, R.H. 1983 MS. *The gaspereau fishery of the SW Margaree River,* 1982. Nova Scotia Department of Fisheries. 10 p.

Table V continued

Species	*Ictalurus nebulosus*	*Fundulus diaphanus*	Gasterosteidae[1]	*Morone americana*	*Perca flavescens*
Anquilla rostrata	-0.152	0.016	-0.394	0.123	0.234
Salvelinus fontinalis	-0.681**	-0.083	0.489*	-0.292	-0.743**
Notemigonus crysoleucas	0.681**	0.287	-0.429	0.095	0.751**
Catostomus commersoni	0.350	0.199	-0.032	0.183	0.425
Ictalurus nebulosus		0.112	-0.569*	0.064	0.850**
Fundulus diaphanus			0.292	0.083	0.035
Gasterosteidae[1]				-0.238	-0.688**
Morone americana					0.148

[1] May include four species.
* Indicates significance at 95% confidence limit.
** Indicates significance at 99% confidence limit.

Cumming, K.J. 1979. *Sportfishing in Nova Scotia. A survey of anglers.* Fisheries and Oceans Canada, Scientific Information and Publications Branch, Ottawa. vi + 62 p.

Edge, T.A. 1984. Preliminary status of the Acadian whitefish (*Coregonus canadensis*) in Nova Scotia. *Canadian Field Naturalist 98(1): 86-90.*

Farmer, G.J., Goff, T.R., Ashfield, D.O., and **Samant, H.S.** 1980. Some effects of the acidification of Atlantic salmon rivers in Nova Scotia. *Can. Tech. Rep. Fish. Aquat. Sci. 972: 13 p.*

Fraser J.M. 1972. Recovery of planted brook trout, splake and rainbow trout from selected Ontario lakes. *J. Fish. Res. Board Can. 29:129-142.*

Fraser, J.M. 1978a. The effect of competition with yellow perch on the survival and growth of planted brook trout, splake, and rainbow trout in a small Ontario lake. *Trans. Am. fish. Soc. 107:505-517.*

Fraser, J.M. 1978b. Comparative recoveries of planted yearling and fall-fingerling brook trout (*Salvelinus fontinalis*) from Ontario lakes. *J. Fish. Res. Board Can. 35:391-396.*

Fraser, J.M. 1981. Comparative survival and growth of planted wild, hybrid, and domestic strains of brook trout (*Salvelinus fontinalis*) in Ontario lakes. *Can. J. Fish. Aquat. Sci. 38:1672-1684.*

Gilhen, J. 1974. *The fishes of Nova Scotia's lakes and streams.* Nova Scotia Museum, Halifax, Nova Scotia. v + 49 p.

Hayes, F.R. 1963. *Chemical characteristics of fresh water.* Great Lakes Research Division, The University of Michigan, 1963. Pub. No. 10:112-117.

Ives, B.H. 1975a. 1973 surveys of eleven lakes in Antigonish and Guysborough counties. Nova Scotia, Resource Development Branch, Fisheries and Marine Service, Halifax, Nova Scotia. *Data Record Series No. MAR/D-75-10, 67 p.*

Ives, B.H. 1975b. 1974 survey inventory of three lakes on the Nine Mile river system, Halifax County and one reclaimed lake in Lunenburg County, Nova Scotia. Resource Development Branch, Fisheries and Marine Service, Halifax, Nova Scotia. *Data Record Series No. MAR/D-75-12, 29 p.*

Jessop, B.M., and **Doubleday, W.G.** 1976. Creel survey and biological study of the striped bass fishery of the Annapolis River, 1975. Department of the Environment, Fisheries and Marine Service, Resource Branch. *Technical Report Series No. MAR/T-76-3. vii + 47 p.*

Jessop, B.M. 1980. Creel survey and biological study of the striped bass fishery of the Annapolis River, 1978. *Can. MS Rep. Fish. Aquat. Sci. No. 1566 x + 20 p.*

Kerekes, J. 1973. *Aquatic resources inventory, Kejimkujik National Park, Nova Scotia. Part 5. Chemical composition of lake and river waters.* Manuscript Report, Canadian Wildlife Service, Environment Canada, 66 p.

Kerekes, J. 1975. *Aquatic resources inventory, Kejimkujik National Park, Nova Scotia. Part 7. Distribution of fishes.* Manuscript Report, Canadian Wildlife Service, Environment Canada, 97 p.

Kerekes, J. 1982. *Fish distribution in Kejimkujik National Park.* P. 57-61. In: Kejimkujik LRTAP Workshop Proc., November 1981.

Kerekes, J. Howell, G., Beauchamp, S., and Pollock, T. 1982. Characterization of three lake basins sensitive to acid precipitation in central Nova Scotia (June 1979 - May 1980). *Int. Revue ges. Hydrobiol 67:679-694.*

Martin, N.V., and **Olver, C.H.** 1976. *The distribution and characteristics of Ontario lake trout lakes.* Ontario Ministry of Natural Resources, Fish and Wildlife Research Branch, Research Report No. 97. 30 p.

McAllister, D.E., Parker, B.J., and **McKee, P.M.** 1985. Rare endangered and extinct fishes in Canada. National Museum of Natural Sciences, Ottawa, *Syllogeus (54)L 1-192.*

Penney, G.H., and **Hiltz, F.M.** 1973. *Results of lake surveys conducted in southwestern Nova Scotia in 1972.* Resource Development Branch, Fisheries Service, Halifax, Nova Scotia. Manuscript Report No. 73-3, 55 p.

Richard, D.M. 1977. Survey of thirteen lakes in Antigonish and Guysborough counties, Nova Scotia, 1976. *Fish. Mar. Serv. Data Rep. No. 47, 37 p.*

Richard, D.M., and **Swan, P.G.** 1979. Survey of sixteen lakes in Antigonish, Guysborough and Digby counties, Nova Scotia, 1977. *Fish. Mar. Serv. Data Rep. No. 122, 31 p.*

Robins, C.R., Bailey, R.M., Bond, C.E., Brooker, J.R., Lachner, E.A., Lea, R.N., and **Scott, W.B.** 1980. *A list of common and scientific names of fishes from the United States and Canada (fourth edition).* American Fisheries Society, Special Publication No. 12, 174 p.

Roland, A.E. 1982. *Geological background and physiography of Nova Scotia.* Inst. of Science, Halifax, N.S. 311 pp.

Ryder, R.A. 1965. A method for estimating the potential fish production of north-temperate lakes. *Trans. Amer. Fish. Soc. 94:214-218.*

Ryder, R.A., Kerr, S.R., Loftus, K.H., and **Regier, H.A.** 1974. The morphoedaophic index, a fish yield estimator - review and evaluation. *J. Fish. Res. Bd. Canada, 31:663-688.*

Sabean, B.C. 1983. *Bras D'Or Lake rainbow fishery.* Nova Scotia Department of Lands and Forests, Technical Note No. 17. 10 p.

Sabean, B.C. 1984. *Black River - Gaspereau Lake creel census 1982.* Nova Scotia Department of Lands and Forests, Technical Note No. 23. 7 p.

Watt, W.D., Scott, C.D., and **White, W.J.** 1983. Evidence of acidification of some Nova Scotia rivers and its impact on Atlantic salmon, *Salmo salar. Can. J. Fish. Aquat. Sci. 40:462-473.*

Welch, P.S. 1948. *Limnological methods.* McGraw Hill Book Co. Inc., Toronto. 381 p.

APPENDIX Location, survey agency, survey date, conductivity, pH, surface area, maximum and mean depth and occurrence of fish species in 781 Nova Scotia lakes surveyed between 1964 and 1981.

Lake	Co-ordinates	Watershed Name	Watershed Code	Survey Agency	Date Mo.	Date Yr.	Conduct. (μmhos/cm)	pH	Surface Area (ha)	Depth Max.	Depth Mean	Fish Species
ANNAPOLIS COUNTY												
Baillie Lake	44°36′N; 65°29′W	Annapolis R.	FA124	L&F	07	75	32.06.0		19.3	6.3	2.0	1,4,5,12
Beelers Lake	44°39′N; 65°31′W	Annapolis R.	FA124	L&F	07	75	39.06.9		20.1	3.3	1.7	1,3,5,12,21
Big Dam Lake (East)	44°28′N; 65°16′W	Mersey R.	SS114	CWS	07	71	23.65.6		45.5	4.2	2.3	1,2,3,4,7,10,12,21
Big Dam Lake (West)	44°28′N; 65°17′W	Mersey R.	SS114	CWS	06,07	71	24.84.9		104.7	9.5	2.5	1,2,3,4,7,10,12,20,21
Big Dam Lake (West)	44°28′N; 65°17′W	Mersey R.	SS114	CWS	08	72	25.05.6		104.7	9.5	2.5	1,2,3,4,5,7,10,12,20,21
Big Molly Upsim L.	44°40′N; 65°03′W	Annapolis R.	FA124	L&F	07	75	26.06.0		507.3	10.5	2.6	1,4,21
Boot Lake	44°34′N; 65°23′W	Mersey R.	SS114	L&F	07	75	32.06.2		119.8	6.0	1.8	1,4,5,12,20,21
Cady Lake	44°37′N; 65°30′W	Moose R.	FA120	L&F	07	75	40.06.7		76.6	4.8	2.5	1,5,10,12
Central Lake	44°26′N; 65°18′W	Mersey R.	SS114	CWS	08	72	25.85.3		68.4	1.8	1.1	1,3,4,5,10,12,21
Lake Clear	44°43′N; 65°18′W	Annapolis R.	FA124	L&F	07	75	37.06.5		21.1	5.7	2.2	1,2,4,5,12,21,29
Connell Lake	44°43′N; 65°03′W	Annapolis R.	FA124	L&F	06	75	28.06.5		16.8	6.6	2.2	1,2,3,4,12,21
Croskill Lake	44°52′N; 65°19′W	Gaskill B.	FA157	L&F	07	75	39.06.6		9.2	7.5	2.3	5
Eleven Mile Lake	44°32′N; 65°17′W	Mersey R.	SS114	L&F	08	75	30.06.2		219.5	2.1	1.1	1,4,5,12,21,26
Elliott Lake	44°56′N; 65°11′W	Elliott L.	FA170	L&F	N/A	N/A	N/AN/A		16.8	8.8	2.1	Not Fished
Fisher Lake	44°43′N; 65°21′W	Mersey R.	SS114	L&F	08	75	32.06.4		396.4	7.5	2.2	1,2,4,5,12,21
Fred Lake	44°35′N; 65°35′W	Bear R.	FA114	L&F	08	75	41.06.6		6.6	3.3	1.4	5
Frozen Ocean Lake	44°27′N; 65°21′W	Mersey R.	SS114	CWS	07	64	29.05.0		227.8	7.6	1.9	1,2,3,4,10,21
Gibson Lake	44°43′N; 65°18′W	Annapolis R.	FA124	L&F	N/A	N/A	N/AN/A		21.1	5.0	2.4	Not Fished
Grand Lake	44°39′N; 65°28′W	Annapolis R.	FA124	L&F	08	75	35.06.5		263.8	15.0	3.8	1,3,4,5,12,21
Jeny Lake	44°43′N; 65°28′W	Annapolis R.	FA124	L&F	07	75	39.06.7		40.5	1.8	0.7	1,4,5,10,21
Lamb Lake	44°40′N; 65°27′W	Annapolis R.	FA124	L&F	07	75	31.06.2		98.8	4.5	1.5	1,3,4,21
Lake LaRose	44°43′N; 65°27′W	Annapolis R.	FA124	L&F	N/A	N/A	N/AN/A		53.8	3.4	2.4	Not Fished
Lake LeMarchant	44°30′N; 65°33′W	Bear L.	FA114	L&F	08	75	29.06.0		120.3	9.0	2.7	1,4,5,10,21
Lily Lake	44°58′N; 65°07′W	Annapolis R.	FA124	L&F	06	75	52.07.0		10.0	6.6	2.4	5
Luxion Lake	44°22′N; 65°21′W	Mersey R.	SS114	CWS	07	72	26.54.8		47.1	8.5	3.0	2,4
McGill Lake	44°41′N; 65°00′W	Annapolis R.	FA124	L&F	07	75	24.06.0		221.5	15.6	4.7	1,3,4,12,21
Milburn Lake	44°50′N; 65°27′W	Lake B.	FA147	L&F	07	75	47.06.7		12.6	5.1	1.7	2,5
Miletree Lake	44°41′N; 64°56′W	LeHave R.	SS95	L&F	06	75	24.06.5		50.7	4.5	2.1	2,4,5,12
Mulgrave Lake	44°31′N; 65°30′W	Bear R.	FA114	L&F	08	75	28.06.8		262.5	12.0	4.2	1,2,4,5,21
Paradise Lake	44°46′N; 65°10′W	Annapolis R.	FA124	L&F	09	75	29.06.2		396.4	9.3	2.5	1,4,12,21

		Watershed		Survey	Date		Conduct.		Surface	Depth		
Lake	Co-ordinates	Name	Code	Agency	Mo.	Yr.	(μmhos/cm)	pH	Area (ha)	Max.	Mean	Fish Species
Pits Lake	44°35′N; 65°24′W	Mersey R.	SS114	L&F	08	75	28.0	5.3	15.4	6.3	2.1	1,2,4,12,21,26
Lake Pleasant	44°37′N; 64°52′W	LaHave R.	SS95	L&F	06	75	24.0	6.0	163.1	7.5	3.3	1,3,4,5,12,21
Quilty Lake	44°43′N; 65°02′W	Annapolis R.	FA124	L&F	06	75	N/A	6.8	32.7	3.0	1.9	4,5
Ramsey Lake	44°54′N; 65°16′W	Poole B.	FA162	L&F	09	81	41.6	7.0	45.8	10.0	3.0	Not Fished
Red Lake	44°26′N; 65°11′W	Mersey R.	SS114	L&F	08	75	37.0	6.1	16.7	3.7	0.9	1,4,21
Sandy Lake	44°55′N; 65°13′W	Starratt B.	FA168	L&F	06	75	47.0	6.8	16.7	9.6	3.9	Fished-No Success
Sandy Bottom Lake	44°35′N; 65°26′W	Mersey R.	SS114	L&F	07	75	32.0	6.0	104.8	12.0	3.1	1,4,21
Shannon Lake	44°45′N; 65°00′W	Annapolis R.	FA124	L&F	06	75	25.0	6.0	98.6	7.5	1.8	1,3,4,10,12,21
Spectacle Lake #1	44°43′N; 65°09′W	Annapolis R.	FA124	L&F	N/A	N/A	N/A	N/A	34.4	4.9	2.7	Not Fished
Spectacle Lake #2	44°43′N; 65°09′W	Annapolis R.	FA124	L&F	N/A	N/A	N/A	N/A	18.2	4.3	2.7	Not Fished
Springfield Lake	44°38′N; 64°52′W	LaHave R.	SS95	L&F	06	75	31.0	6.1	88.1	3.0	2.1	1,3,4,5,12,20,21
Sundown Lake	44°32′N; 65°25′W	Bear R.	FA114	L&F	08	75	29.0	6.5	12.8	5.1	2.9	2,4,5,12,21
Tommy Lake	44°35′N; 64°59′W	Medway R.	SS106	L&F	06	75	24.0	5.2	26.2	8.1	2.8	1,4,5,12
Trout Lake	44°46′N; 65°04′W	Annapolis R.	FA124	L&F	06	75	25.0	6.1	170.9	7.2	2.2	2,3,4,12,21
Unnamed	44°35′N; 65°24′W	Mersey R.	SS114	L&F	08	75	35.0	6.0	12.6	6.9	2.6	1,4,12,21,26
Unnamed	44°58′N; 65°06′W	Annapolis R.	FA124	L&F	05	75	54.0	6.8	7.3	1.5	0.8	5
Unnamed	44°44′N; 65°22′W	Annapolis R.	FA124	L&F	07	75	34.0	6.7	8.9	5.1	1.9	1,5,12
Upper Lake	44°30′N; 65°32′W	Bear R.	FA114	L&F	08	75	30.0	6.1	43.6	2.1	1.3	1,4,21
Upper Mink Lake	44°33′N; 65°28′W	Bear R.	FA114	L&F	08	75	25.0	6.0	20.7	6.6	2.3	1,2,4,5,12,21
View Lake	44°32′N; 65°21′W	Jordan R.	SS114	L&F	08	75	38.0	6.0	12.5	4.5	1.9	1,2,4,5,12,21
Waterloo Lake	44°44′N; 64°59′W	Annapolis R.	FA124	L&F	06	75	30.0	6.2	133.8	9.0	2.4	1,3,4,5,21
Wild Duck Lake	44°37′N; 64°56′W	Medway R.	SS106	L&F	06	75	25.0	5.4	10.4	7.2	1.8	2,4,5,12,21
Young Lake	44°49′N; 65°26′W	Hogan B.	FA148	L&F	07	75	N/A	N/A	3.2	3.0	1.8	2,5
Zwicker Lake	44°44′N; 65°02′W	Annapolis R.	FA124	L&F	06	75	36.0	6.8	51.5	6.0	2.8	1,2,3,4,5,12,21
ANTIGONISH COUNTY												
Cameron Lake	45°31′N; 61°59′W	South R.	NS48	DFO	07	73	55.2	6.4	29.6	9.5	4.8	1,2,3,4,10,12,18
College Lake	45°25′N; 62°05′W	West R.	NS51	DFO	06	76	28.0	5.4	4.0	1.0	0.3	2
Gaspereaux Lake	45°33′N; 62°03′W	West R.	NS51	DFO	08	73	153.3	8.0	87.1	4.6	1.9	1,3,4,10,12,21
Gaspereaux Lake	45°33′N; 62°03′W	West R.	NS51	L&F	08	75	220.0	9.2	87.1	4.6	1.9	1,3,4,5,10,12,21
Gillis Lake	45°32′N; 61°58′W	South R.	NS48	DFO	07	73	74.2	6.3	28.0	10.7	3.9	1,2,3,4,10,12,18
Gillis Lake	45°32′N; 61°58′W	South R.	NS48	L&F	08	75	108.0	7.0	28.0	10.7	3.9	1,3,4,5,12,14,17,18
Kimballs Lake	45°24′N; 61°57′W	South R.	NS48	L&F	06	77	35.0	7.0	2.8	7.5	2.6	2
Lochaber Lake	45°25′N; 62°02′W	St. Mary's R.	ES142	DFO	08	73	46.6	6.8	307.0	52.4	21.8	1,2,3,4,10,17,21

		Watershed		Survey	Date		Conduct.		Surface	Depth		
Lake	Co-ordinates	Name	Code	Agency	Mo.	Yr.	(μmhos/cm)	pH	Area (ha)	Max.	Mean	Fish Species
Loch Katrine Lake	45°26′N; 61°56′W	South R.	NS48	DFO	08	77	39.5	6.8	112.1	27.0	10.0	1,3,4,7,12
McKay Lake	45°28′N; 62°07′W	West R.	NS51	L&F	08	79	30.0	7.0	8.8	2.0	1.1	2
Monastery Lake	45°36′N; 61°37′W	Tracadie R.	NS23	L&F	07	74	44.0	6.3	21.2	16.8	5.9	1,2,7
Polson Lake	45°24′N; 61°59′W	South R.	NS48	DFO	07	76	42.5	6.2	19.5	15.0	5.9	1,2,7
Pomquet Lake	45°37′N; 61°50′W	Pomquet R.	NS36	DFO	06	76	25900.0	8.1	17.4	5.8	1.4	3
St. Joseph's Lake	45°32′N; 61°05′W	West R.	NS51	L&F	08	75	320.0	7.3	19.9	5.4	3.0	1,2,3,4,5,10
Tracadie Lake	45°37′N; 61°36′W	Tracadie R.	NS23	L&F	07	75	140.0	7.0	27.7	10.7	1.9	1,2,3,5,15
Unnamed Lake	45°24′N; 61°58′W	South R.	NS48	DFO	06	77	44.0	6.8	2.1	4.7	2.4	1,2
Unnamed Lake	45°30′N; 61°55′W	South R.	NS48	DFO	08	77	65.0	6.3	2.4	4.5	2.4	1,4
CAPE BRETON COUNTY												
AECL Plant Dam	46°12′N; 59°58′W	None	CBE78	L&F	08	77	117.0	6.0	12.6	7.5	4.0	15
Barachois Pond No.1	45°53′N; 59°59′W	None	CBE123	CWS	08	80	1035.0	6.7	1.7	0.9	0.5	Fished-No Success
Barachois Pond No.2	45°63′N; 59°60′W	None	CBE123	CWS	08	80	76.0	5.7	2.2	0.8	0.5	Fished-No Success
Barachois Pond No.3	45°53′N; 59°59′W	None	CBE123	CWS	08	80	328.0	6.7	0.7	0.7	0.5	Fished-No Success
Barachois Pond No.5	45°53′N; 59°59′W	None	CBE122	CWS	08	80	96.0	6.6	2.8	2.1	1.4	Fished-No Success
Barachois Pond No.6	45°53′N; 59°59′W	None	CBE122	CWS	08	80	30400.0	8.5	2.6	1.1	0.4	10
Barachois Pond No.8	45°53′N; 59°59′W	None	CBE123	CWS	08	80	110.0	6.8	0.3	0.4	0.2	Fished-No Success
Belle Lake	45°57′N; 60°06′W	Catalone R.	CBE108	DFO	08	75	30.0	6.6	39.7	2.0	1.4	2
Blacketts Lake	46°04′N; 60°18′W	Sydney R.	CBE58	DFO	07	75	130.0	7.2	171.1	30.0	9.5	1,2,3,10
Browns Lake	46°11′N; 60°10′W	Northwest B.	CBE71	DFO	06	75	40.0	6.4	25.8	2.0	0.9	2
Catalone Lake	46°00′N; 59°57′W	Mira Bay	CBE104	L&F	07	80	N/A	7.5	250.1	10.0	3.4	Not Fished
Cavanagh Lake	45°55′N; 60°02′W	Landing Cove B.	CBE125	CWS	08	80	46.0	6.2	31.9	3.1	1.1	2,10,15
Cochran Lake	46°06′N; 60°00′W	Mira R.	CBE104	DFO	07	75	50.0	4.7	37.6	1.9	0.5	Fished-No Success
Cranberry Lake	46°03′N; 60°10′W	Sydney R.	CBE58	DFO	07	75	29.0	5.8	57.3	0.5	0.2	Not Fished
Dumaresq Lake	46°04′N; 60°08′W	Mira Bay	CBE104	L&F	07	80	37.0	6.0	64.2	4.0	2.1	1,3,5,10,21
Figure of Eight Lake	45°48′N; 60°18′W	Mira R.	CBE104	L&F	08	77	N/A	7.0	33.0	3.6	1.9	3,5
Forester Lake	46°08′N; 60°21′W	Leitches Creek	CBE50	L&F	07	76	N/A	7.5	104.0	16.7	3.7	Not Fished
Front Lake	46°03′N; 60°11′W	Sydney R.	CBE58	DFO	07	75	28.0	6.4	67.3	4.0	2.1	1,2,3
Gabarus Lake	45°49′N; 60°12′W	Belfry L.	CBE145	L&F	07	77	83.0	7.0	440.0	16.0	4.2	2,3
Gillies Lake	46°03′N; 60°24′W	Gillies B.	CBE225	L&F	08	76	N/A	7.0	45.3	22.8	9.6	2,5,12,15
Gillies Lake	46°04′N; 60°18′W	Sydney R.	CBE58	L&F	06	80	35.0	7.5	11.6	5.0	2.3	1,2,3,5,15
Grand Lake	45°58′N; 59°57′W	Grand L.	CBE120	L&F	07	80	46.0	6.5	119.9	4.0	2.0	2,26
Inglis Lake	46°10′N; 60°09′W	Sydney R.	CBE58	DFO	06	75	25.0	6.4	25.3	2.0	1.2	Fished-No Success

Lake	Co-ordinates	Watershed Name	Watershed Code	Survey Agency	Date Mo.	Date Yr.	Conduct. (μmhos/cm)	pH	Surface Area (ha)	Depth Max.	Depth Mean	Fish Species
Joe Lake	46°04'N; 60°13'W	Sydney R.	CBE58	DFO	07	75	32.0	6.6	33.2	4.0	1.3	1,2,3,12
Johnson Lake	46°10'N; 60°19'W	Limestone B.	CBE49	L&F	07	77	60.0	7.0	32.0	10.0	4.4	3,5,15,18
Kehoe Lake	46°11'N; 60°08'W	Northwest B.	CBE71	L&F	08	80	56.0	6.5	14.3	2.0	0.7	Fished-No Success
Kelly Lake	45°55'N; 60°01'W	Gerard B.	CBE121	CWS	08	80	40.0	6.2	25.6	N/A	N/A	2
Kilkenny Lake	46°12'N; 60°09'W	Northwest B.	CBE71	DFO	06	75	N/A	5.0	58.7	5.0	1.8	2
Long Lake	45°50'N; 60°12'W	Belfry L.	CBE145	DFO	08	75	400.0	6.2	27.4	27.0	7.4	2
Loon Lake	46°05'N; 59°58'W	Mill Stream	CBE101	DFO	06	75	54.0	6.6	36.7	2.0	0.7	2,3,12,18
Loon Lake	46°02'N; 60°30'W	MacIntosh B.	CBE238	L&F	08	77	30.0	7.0	61.5	4.5	2.7	2,5
Mathieson Lake	45°54'N; 60°05'W	Kennington Cove	CBE128	CWS	08	80	39.0	5.8	9.1	2.0	1.0	2,10,15
MacDonald Lake	46°00'N; 60°01'W	Mira R.	CBE104	L&F	08	80	550.0	7.5	21.0	6.0	3.1	2,15
MacIntyres Lake	45°58'N; 60°06'W	Catalone R.	CBE108	L&F	08	77	135.0	7.0	27.0	12.8	2.8	1,2,12
MacNeil Lake	45°51'N; 60°31'W	Mira R.	CBE104	L&F	08	80	32.0	6.3	12.9	4.0	1.8	1,2,3,5,10,15
McAdams Lake	46°02'N; 60°26'W	Gillies B.	CBE225	DFO	07	75	35.0	6.5	31.3	10.0	3.5	1,2,3
McAdams Lake	46°02'N; 60°26'W	Gillies B.	CBE225	L&F	08	76	N/A	6.5	31.3	10.0	3.5	2,3
McDougall Lake	45°52'N; 60°20'W	Mira R.	CBE104	L&F	08	80	36.0	6.5	16.2	12.0	3.0	1,2,3,18,21
McInnes Lake	46°01'N; 60°19'W	Sydney R.	CBE58	L&F	08	80	52.0	7.0	3.3	10.0	3.5	1,3,12
McInnes Lake	45°57'N; 60°09'W	Catalone R.	CBE108	L&F	08	77	38.0	6.5	32.0	7.3	3.0	1,2,12
Morrison Lake	46°04'N; 60°08'W	Mira R.	CBE10	L&F	07	80	66.0	5.5	10.9	1.0	0.7	21
No. 20 Dam	46°12'N; 59°58'W	Renwick B.	CBE79	DFO	07	75	35.0	6.0	11.6	1.0	0.8	2,8
Scotch Lake	46°11'N; 60°21'W	Almon Creek	CBE282	DFO	07	75	38.0	6.1	28.0	4.0	2.1	2,12
Spectacle Lake No. 1	45°53'N; 60°06'W	Spectacle L.	CBE130	CWS	08	80	42.0	4.7	5.8	N/A	N/A	2
Spectacle Lake No. 2	45°53'N; 60°06'W	Spectacle L.	CBE130	CWS	08	80	45.0	4.7	3.4	N/A	N/A	2
String Lake	45°53'N; 60°13'W	Mira R.	CBE104	L&F	07	77	52.0	6.8	18.0	6.0	3.0	1,3,5
Twelve Mile Lake	45°54'N; 60°08'W	Kennington Cove B.	CBE128	CWS	08	80	40.0	6.6	74.0	3.5	1.4	2,10,15
COLCHESTER COUNTY												
Bob Lake	45°16'N; 63°10'W	Shubenacadie R.	MB92	L&F	07	73	28.0	8.5	2.0	2.1	N/A	Not fished
Byers Lake	45°25'N; 63°25'W	French R.	NS191	L&F	07	73	32.0	6.5	5.5	6.1	N/A	2,5
Clear Lake	44°35'N; 63°20'W	Chiganois R.	MBC18	L&F	09	77	21.0	6.5	7.6	6.0	1.7	2
Cook Lake	45°32'N; 63°24'W	Debert R.	MB96	L&F	07	79	26.0	6.0	3.0	7.0	1.7	2
Deyarmont Lake	45°18'N; 63°01'W	Shubenacadie R.	MB92	L&F	07	73	23.0	6.5	27.1	7.6	N/A	2,21
Economy Lake	45°29'N; 63°52'W	Economy R.	MB119	L&F	08	73	N/A	6.0	70.0	4.6	N/A	2,5
Farm Lake	45°33'N; 63°21'W	Chiganois R.	MBC18	L&F	07	77	30.0	6.8	15.4	5.0	2.0	2,5

Lake	Co-ordinates	Watershed Name	Watershed Code	Survey Agency	Date Mo.	Date Yr.	Conduct. (µmhos/cm)	pH	Surface Area (ha)	Depth Max.	Depth Mean	Fish Species
Frog Lake	45°31′N; 63°23′W	Chiganois R.	MBC18	L&F	07	73	24.0	6.0	9.3	9.1	N/A	2
Glenholme Lake	45°24′N; 63°32′W	None	MB98	L&F	07	73	27.0	6.0	9.7	5.2	N/A	4,5,15
Guyon Lake	45°33′N; 63°24′W	Chiganois R.	MBC18	L&F	08	77	21.0	6.5	6.0	5.2	1.6	2
Hart Lake	45°35′N; 63°31′W	Wallace R.	NS210	L&F	06	73	18.0	6.5	38.9	22.9	N/A	2
Hay Lake	45°18′N; 63°01′W	Subenacadie R.	MB92	L&F	07	73	N/A	6.5	10.1	1.8	N/A	5,15
Irvine Lake	45°34′N; 63°24′W	Debert R.	MB96	L&F	08	77	21.0	6.0	5.8	2.0	0.7	2,5
Long Lake	45°16′N; 63°10′W	Shubenacadie R.	MB92	L&F	06	73	N/A	6.5	6.5	3.4	N/A	Not fished
Moose Lake	45°22′N; 63°01′W	Shubenacadie R.	MB92	L&F	07	73	14.5	6.0	15.4	7.6	N/A	2,15
Shortts Lake	45°13′N; 63°19′W	Shubenacadie R.	MB92	L&F	07	73	85.0	7.5	178.1	13.7	N/A	1,3,4,5,13,15
Simpson Lake	45°31′N; 63°57′W	Economy R.	MB119	L&F	08	73	20.5	6.8	47.8	12.2	N/A	1,2
Twin Lake	45°18′N; 63°03′W	Shubenacadie R.	MB92	L&F	06	73	18.0	6.0	16.6	2.1	N/A	2,5,15,21
Whippey Lake	45°35′N; 63°19′W	Chiganois R.	MBC18	L&F	07	77	28.0	6.0	3.0	2.0	0.7	2
CUMBERLAND COUNTY												
Big Lake	46°43′N; 63°43′W	Pugwash R.	NS224	L&F	08	62	N/A	7.0	N/A	12.2	3.0	1,3,4,5,10,12,21
Big Lake	45°43′N; 63°43′W	Pugwash R.	NS224	L&F	07	73	43.0	7.0	93.1	10.7	3.1	1,3,4,12
Blair Lake	45°48′N; 64°13′W	Maccan R.	MB224	L&F	08	73	20.0	8.0	45.3	6.1	N/A	1,3
Dewar Lake	45°44′N; 63°31′W	Dewar R.	NS197	L&F	07	73	38.0	7.0	124.2	12.2	N/A	1,3,4,12
Folly Lake	45°32′N; 63°33′W	Folly R.	MB96	L&F	06	73	55.0	7.0	78.9	33.5	N/A	2,5,12
Gilbert Lake	45°28′N; 64°20′W	River Hebert	MB223	L&F	07	73	N/A	7.0	22.7	9.1	N/A	1,3,4,5,9,12,13,18,37
Harrison Lake	45°42′N; 64°16′W	Maccan R.	MB224	L&F	08	74	55.0	7.0	134.4	4.6	N/A	1,5,7,15
Isaac Lake	45°33′N; 63°42′W	Portapique R.	MB106	L&F	08	73	25.0	7.0	16.2	7.6	N/A	2,5,15,16
Lake Killarney	45°51′N; 63°51′W	River Philip	NS225	L&F	08	73	42.0	7.0	76.9	6.1	N/A	1,2,3,4,12,21
La Planche Lake	45°53′N; 64°09′W	La Planch R.	MB233	L&F	07	79	48.0	6.5	1.8	1.0	0.5	1,3,21
Laytons Lake	45°48′N; 64°15′W	Forrest B.	MB227	CWS	07,08	73	468.0	7.5	11.3	11.0	2.1	1,3,5,10,12,15,23
Leak Lake	45°26′N; 64°21′W	Parrsboro R.	MB146	L&F	06	62	N/A	7.1	14.6	12.2	4.0	5
Leak Lake	45°26′N; 64°21′W	Parrsboro R.	MB146	L&F	06	73	N/A	7.0	14.6	12.2	N/A	1,2,6,12
Long Lake	45°54′N; 64°09′W	La Planch R.	MB233	L&F	09	73	46.0	7.0	85.0	1.5	N/A	3,5,12,21
Mattatall Lake	45°41′N; 63°29′W	French R.	NS191	L&F	07	73	32.0	7.5	106.8	10.7	N/A	1,3,4,12,21
Newville Lake	45°31′N; 64°20′W	River Hebert	MB223	L&F	08	73	N/A	6.5	78.5	7.6	N/A	1,3,5,12,13,17
Park Lake	45°43′N; 63°53′W	River Philip	NS225	L&F	08	73	12400.0	8.0	4.9	9.1	N/A	5
Pineo Lake	45°46′N; 63°41′W	Pugwash R.	NS224	L&F	08	73	64.0	7.0	16.2	3.1	N/A	1,3,4,10,21
Pleasant Lake	45°26′N; 64°20′W	Parrsboro R.	MB146	L&F	06	62	62.0	6.8	15.8	7.6	N/A	2,10,12
Pleasant Lake	45°26′N; 64°20′W	Parrsboro R.	MB146	L&F	06	73	62.0	7.0	15.8	7.6	N/A	1,2,15,20

		Watershed		Survey	Date		Conduct.		Surface	Depth		
Lake	Co-ordinates	Name	Code	Agency	Mo.	Yr.	(µmhos/cm)	pH	Area (ha)	Max.	Mean	Fish Species
Poison Lake	45°33′N; 63°56′W	River Philip	NS225	L&F	08	73	27.0	6.5	3.2	4.6	N/A	2,5
Slade Lake	45°43′N; 63°55′W	River Philip	NS225	L&F	08	73	106.0	7.0	14.2	27.4	N/A	2,3,4,12
Smith Lake	45°53′N; 64°11′W	La Planch R.	MB233	L&F	07	79	37.0	6.5	7.5	1.0	0.5	1,3,4,21
Sutherland Lake	45°31′N; 63°41′W	Portapique R.	MB106	L&F	08	73	20.5	6.7	42.1	6.1	N/A	2,5,16
Vickery Lake	45°43′N; 63°54′W	River Philip	NS225	L&F	08	73	160.0	7.0	8.5	33.6	N/A	1,2,12,20
Welton Lake	45°29′N; 64°29′W	River Hebert	MB223	L&F	08	62	29.0	6.5	27.9	3.9	2.7	1,3,4,5,12
Welton Lake	45°29′N; 64°29′W	River Hebert	MB223	L&F	08	73	29.0	6.5	27.9	3.9	2.7	5,15
West Branch Lake	45°32′N; 63°57′W	River Philip	NS225	L&F	08	73	16.0	6.0	14.6	9.1	N/A	2,5
Wigmore Lake	45°44′N; 63°38′W	Wallace R.	NS210	L&F	07	73	N/A	6.5	18.6	3.1	N/A	3,4,12,21
DIGBY COUNTY												
Big Red Lake	44°21′N; 65°23′W	Mersey R.	SS114	CWS	07	72	35.8	4.4	70.5	2.2	1.0	4
Boarback Lake	44°09′N; 65°57′W	Tusket B.	FA53	DFO	08	77	45.0	5.0	26.8	9.0	2.4	Fished-No Success
Bull Lake	44°19′N; 66°01′W	Meteghen R.	FA71	L&F	08	79	40.0	6.0	14.4	4.0	1.9	1,2,3,4,12,21
Cedar Lake	44°01′N; 66°07′W	Beaver R.	FA67	L&F	07	81	69.0	6.6	91.1	8.0	2.9	1,3,4,12,15,21
Cedar Lake	44°01′N; 66°07′W	Beaver R.	FA67	DFO	08	74	N/A	N/A	103.6	7.0	2.2	1,3,4,12,18,21
Clearwater Lake	44°12′N; 66°05′W	Salmon R.	FA69	L&F	N/A	N/A	N/A	N/A	156.2	11.6	5.2	Not Fished
Clearwater Lake	44°17′N; 65°57′W	Clearwater L.	N/A	L&F	N/A	N/A	N/A	N/A	20.2	7.2	4.6	Not Fished
Clearwater Lake	44°12′N; 66°03′W	Salmon R.	FA69	L&F	08	81	N/A	6.5	122.4	12.0	4.2	1,2,3,4,5,18,21
Comeau Lake	44°15′N; 65°59′W	Meteghan R.	FA71	L&F	N/A	N/A	N/A	N/A	53.1	3.0	N/A	Not Fished
Hectanooga Lake	44°06′N; 66°02′W	Salmon R.	FA69	L&F	08	68	N/A	N/A	25.5	6.1	2.4	1,2,3,4,12,21
Hourglass Lake	44°20′N; 65°56′W	Tusket R.	FA53	L&F	08	68	N/A	N/A	30.3	6.1	2.7	1,2,3,21
Jib Lake	44°19′N; 66°00′W	Metaghan R.	MB71	L&F	08	79	35.0	6.3	25.0	2.0	0.9	1,4,21
Knockwood Lake	44°25′N; 65°44′W	Sissiboo R.	FA79	L&F	08	81	35.4	6.3	36.4	8.0	2.9	1,2,5,12,15,20,21
Little Red Lake	44°20′N; 65°24′W	Mersey R.	SS114	CWS	08	72	32.6	4.5	19.6	1.3	0.7	4
Lower Corning Lake	44°03′N; 66°05′W	Salmon R.	FA69	DFO	08	74	49.0	6.7	68.0	4.0	1.5	1,3,4,21
Lower Corning Lake	44°03′N; 66°05′W	Salmon R.	FA69	L&F	07	81	54.0	6.5	60.4	4.5	2.2	1,3,9,10,21
Midway Lake	44°32′N; 66°03′W	Midway L.	FA93	L&F	N/A	N/A	N/A	N/A	66.0	2.3	N/A	2
Napier Lake	44°12′N; 65°43′W	Tusket R.	FA53	L&F	07	74	40.0	4.0	48.7	7.9	2.0	2,4,5
North Doucette Lake	44°19′N; 66°07′W	North Doucette L.	FA76	L&F	N/A	N/A	N/A	N/A	12.8	N/A	1.2	2
Norwood Clearwater L.	44°03′N; 66°03′W	Salmon R.	FA69	L&F	07	81	54.0	6.5	30.8	10.0	3.1	2,5,27
Pebbleloggitch Lake	44°18′N; 65°21′W	Mersey R.	SS114	CWS	06,07	71	27.3	4.5	33.7	2.5	1.6	4,10,21
Pebbleloggitch Lake	44°18′N; 65°21′W	Mersey R.	SS114	CWS	06	72	29.3	4.4	33.7	2.5	1.6	4,10,21
Peskawa Lake	44°19′N; 65°22′W	Mersey R.	SS114	CWS	06,07	71	26.4	4.5	388.0	9.0	3.2	1,2,4,5,12,21

Lake	Co-ordinates	Watershed		Survey Agency	Date		Conduct. (µmhos/cm)	pH	Surface Area (ha)	Depth		Fish Species
		Name	Code		Mo.	Yr.				Max.	Mean	
Peskawa Lake	44°19′N; 65°22′W	Mersey R.	SS114	CWS	07,08	72	28.4	4.7	388.0	9.0	3.2	1,2,4,5,12,21
Pierce Lake	44°03′N; 66°07′W	Salmon R.	FA69	DFO	08	74	58.0	6.7	30.8	6.0	2.3	2,3,21
Porcupine Lake	44°16′N; 65°56′W	Tusket R.	FA53	L&F	N/A	N/A	N/A	N/A	147.0	12.2	3.7	Not Fished
Snare Lake	44°00′N; 65°51′W	Tusket R.	FA53	DFO	08	74	45.9	5.8	52.0	2.0	1.0	1,3,4,21
Tedford Lake	44°06′N; 66°01′W	Salmon R.	FA69	DFO	08	77	47.3	6.7	82.2	4.8	1.9	3,21
Youngs Lake	44°16′N; 66°05′W	LeBlanc B.	FA74	L&F	N/A	N/A	N/A	N/A	10.5	N/A	2.1	Not Fished
GUYSBOROUGH COUNTY												
Archibald Lake	45°12′N; 61°57′W	St. Mary's R.	ES142	L&F	08	76	47.0	5.5	128.0	10.9	2.1	2,15
Archibalds Big Lake	45°18′N; 61°48′W	Howlett B.	ES121	L&F	09	81	N/A	6.3	82.5	8.3	3.5	2
Ash Lake	45°05′N; 62°13′W	Ecum Secum R.	ES165	L&F	07	81	24.1	6.5	21.8	7.4	1.8	1,2,5,12,15
Auld Lake	45°37′N; 61°26′W	Mill Creek	NS5	L&F	08	74	N/A	8.5	5.2	1.8	0.8	1
Bear Lake	45°02′N; 62°18′W	Moser R.	ES171	L&F	08	77	34.0	6.7	6.6	6.0	2.7	2,15
Bear Lake	45°03′N; 61°59′W	Gaspereaux B.	ES149	L&F	08	81	30.1	6.0	6.3	5.2	0.2	2
Beaver Dam L. No.2	45°20′N; 61°47′W	Salmon R.	ES29	DFO	07	78	20.0	6.5	8.5	6.0	2.3	1,4,12,17,18,21
Big Gaspereaux Lake	45°06′N; 62°04′W	Gaspereaux B.	ES149	L&F	08	78	35.0	6.0	325.5	9.0	3.3	1,3,14,18
Bottle Brook Lake	45°15′N; 62°35′W	East R.	ES185	L&F	07	73	12.0	5.8	37.6	9.1	N/A	1,2,21
Bull Moose L. (Grassy)	45°03′N; 62°14′W	Ecum Secum R.	ES165	L&F	07	81	26.8	6.0	10.9	6.0	1.6	1,2,5,15,21
Caribou Lake	45°16′N; 62°34′W	East R.	ES185	L&F	08	73	16.5	5.5	11.3	3.7	N/A	1,2
Cavanaugh Lake	45°20′N; 61°07′W	None	ES42	L&F	06	74	50.0	4.5	6.0	1.5	0.6	Not fished
Charlie Lake	45°23′N; 61°52′W	Salmon R.	ES29	DFO	08	73	28.7	6.8	17.4	10.7	4.2	1,2,4,7,18
Cochran Lake	45°20′N; 61°54′W	Country Hbr. R.	ES122	DFO	06	76	47.5	6.7	26.1	11.0	4.1	1,2,4
Cooper Lake	45°05′N; 61°53′W	Cooper L.	ES140	L&F	08	77	36.0	6.0	27.6	3.0	1.2	2,3,4,12,13,15
Cross Lake	45°25′N; 61°51′W	Salmon R.	ES29	DFO	08	73	25.6	6.5	116.6	7.3	3.4	1,2,4,10,12,13
Cuddihy Lake	45°27′N; 61°43′W	Guysborough R.	ES27	DFO	07	76	81.0	6.0	18.8	11.0	4.3	2,12
Cummingar Lake	45°16′N; 62°03′W	St. Mary's R.	ES142	L&F	08	77	40.0	6.7	29.4	9.0	2.0	1,3,4,5,12,13,15,18,21
Dayspring Lake	45°13′N; 62°35′W	East R.	ES185	L&F	06	73	18.0	6.0	27.5	4.6	N/A	1,2,21
Dobson Lake	45°20′N; 61°12′W	Cole Harbour R.	ES82	L&F	06	74	45.0	5.5	46.8	7.6	2.3	2,5
Duggans Lake	45°20′N; 61°47′W	Salmon R.	ES29	DFO	06	77	20.0	6.0	5.4	8.4	2.9	1,2,4,12
Dummy Gillis Lake	45°20′N; 61°56′W	Country Hbr. R.	ES122	DFO	08	76	20.0	5.6	4.0	5.0	2.6	2,4,5,10
Eight Island Lake	45°21′N; 61°57′W	Country Hbr. R.	ES122	DFO	08	73	37.9	6.3	91.3	10.1	3.6	1,3,4,10,18,21
First Rocky Lake	45°14′N; 62°32′W	East River	ES185	L&F	07	73	11.0	6.0	51.0	7.6	N/A	1,2,15,21
Fitzgerald Lake	45°28′N; 61°44′W	Guysborough R.	ES27	DFO	07	76	156.0	7.3	21.6	2.0	0.4	1,2,7
Frog Lake	45°17′N; 61°55′W	Country Hbr. R.	ES122	DFO	06	76	20.3	5.7	5.6	4.0	1.9	1,4,12,18,21

Lake	Co-ordinates	Watershed Name	Watershed Code	Survey Agency	Date Mo.	Date Yr.	Conduct. (μmhos/cm)	pH	Surface Area (ha)	Depth Max.	Depth Mean	Fish Species
Garry Lake No.3	45°20′N; 61°41′W	Isaac's Harbour R.	ES112	DFO	08	77	20.0	6.0	8.8	5.5	1.5	1,2
Garry Lake No.2	45°20′N; 61°41′W	Isaac's Harbour R.	ES112	DFO	08	77	20.0	6.0	8.9	2.2	1.0	1,2
Gegogan Lake	45°05′N; 62°00′W	Gegogan B.	ES146	L&F	08	79	40.0	6.2	24.0	5.2	1.1	1,2,4,5,10,12,13,15,18
Giants Lake	45°23′N; 61°53′W	South R.	NS48	DFO	08	73	26.1	6.4	57.0	12.2	3.7	1,2,10
Glenelg Lake	45°16′N; 62°04′W	St. Mary's R.	ES142	L&F	08	78	20.0	6.6	110.8	16.0	3.9	1,5,12,14,15
Goose Harbour Lake	45°33′N; 61°25′W	St. Francis R.	ES20	L&F	07	74	29.0	6.5	353.4	9.1	3.3	1,2,10,12,15
Grassy Lake	45°06′N; 62°00′W	Geogogan B.	ES146	L&F	08	77	51.0	5.7	15.0	1.5	0.4	1,12
Hazel Hill Lake	45°19′N; 61°01′W	Gaspereau B.	ES48	L&F	07	74	55.0	5.5	44.1	3.1	3.7	2,5,15
Hooper Lake	45°01′N; 62°03′W	Hooper B.	ES151	L&F	07	81	36.4	6.0	15.2	6.0	2.5	1,2
Hughie Lake	45°28′N; 61°45′W	Black R.	NS36	DFO	07	76	31.0	6.7	19.1	3.0	1.3	1,2
Hurley Lake	45°19′N; 61°49′W	Country Hbr. R.	ES122	DFO	07,08	76	23.4	6.8	36.4	12.0	3.9	1,2,9
Ice Lake	45°20′N; 61°01′W	None	ES44	L&F	07	74	90.0	6.5	6.0	3.0	1.1	1,15
Indian Harbour L. (Big)	45°07′N; 61°51′W	Indian Harbour R.	ES136	L&F	07	76	4500.0	N/A	142.0	3.0	1.6	3,5,36
Indian Harbour Lake	45°10′N; 61°57′W	Indian Harbour R.	ES136	L&F	07	76	71.0	6.5	17.4	27.0	7.3	2,3,18
Irving Lake	45°26′N; 61°32′W	Guysborough R.	ES27	L&F	07	74	31.0	6.0	4.4	10.7	2.6	2,5
Johnsons Lake	45°23′N; 61°41′W	County Hbr. R.	ES122	DFO	06	77	40.0	7.0	4.8	11.8	3.7	1,3,4,18
Kelly Lake	45°23′N; 61°47′W	Salmon R.	ES29	DFO	06	76	30.0	6.1	25.9	6.0	2.3	1,2,4,5,10
Kirby Lake	45°01′N; 62°04′W	Mullen Mill B.	ES153	L&F	07	81	35.4	5.5	15.9	8.0	2.8	1,2,15
Lawhie Lake	45°21′N; 61°56′W	Country Hbr. R.	ES122	DFO	06	76	31.4	5.8	16.2	10.5	2.3	1,2,4,5,6
Long John Lake	45°16′N; 62°33′W	St. Mary's R.	ES142	L&F	07	78	43.0	5.8	17.8	12.0	3.4	20
Long Lake	45°22′N; 62°13′W	St. Mary's R.	ES142	L&F	07	75	20.0	6.2	22.5	6.0	2.1	1,12
Louse Lake	44°58′N; 62°06′W	Louse L.	ES161	L&F	07	81	107.0	6.0	3.0	2.3	1.0	2
Lower Gaspereaux L.	45°04′N; 62°02′W	Gaspereaux B.	ES149	L&F	08	81	27.3	6.0	91.8	10.0	2.7	1,2,18
Lower Rocky Lake	45°12′N; 62°33′W	East R.	ES185	L&F	07	73	11.0	6.2	116.6	7.6	N/A	1,2,21
MacPherson Lake	45°26′N; 61°25′W	Clam Pond	NS24	L&F	06	74	41.0	7.0	86.5	29.0	9.1	1,2,12,15
Magginist Lake	45°24′N; 61°53′W	South R.	NS48	DFO	05	75	20.0	6.7	8.8	2.0	0.9	1,2,12
Mannassette Lake	45°26′N; 61°20′W	Collins Pond	ES22	L&F	06	74	45.0	6.5	13.8	7.9	6.0	1,2,3,18
Margaret Lake	45°24′N; 61°56′W	South R.	NS48	DFO	06	77	31.0	6.5	4.1	2.5	1.3	1,2
Mattie Lake	45°36′N; 61°28′W	Mill Creek	NS5	DFO	07	76	35.0	5.9	30.1	7.0	2.2	1,2
MacKinnons Lake	45°24′N; 61°54′W	South R.	NS48	DFO	06	77	44.0	7.0	5.7	9.5	3.0	7,12
McLeod Lake	45°16′N; 62°09′W	St. Mary's R.	ES142	DFO	07	76	28.5	6.4	33.0	8.5	3.1	1,3,4,12,21
McLeod Lake	45°16′N; 62°09′W	St. Mary's R.	ES142	L&F	09	77	30.0	6.5	29.4	9.0	3.7	1,2,3,4,5,6,12,13,14
McMullin Lake	46°16′N; 61°58′W	St. Mary's R.	ES142	DFO	07	76	247.0	6.0	14.2	2.5	1.4	1,4,18,21
Middle (Sand) Lake	45°17′N; 61°12′W	Cole Harbour Road	ES82	L&F	09	80	N/A	6.0	37.9	12.0	4.0	2,5,12

Lake	Co-ordinates	Watershed Name	Watershed Code	Survey Agency	Date Mo.	Date Yr.	Conduct. (μmhos/cm)	pH	Surface Area (ha)	Depth Max.	Depth Mean	Fish Species
Mitchell Lake	45°08′N; 62°04′W	Gaspereaux B.	ES149	L&F	08	78	24.0	6.3	133.6	16.0	4.9	Fished-No Success
Mud Lake	45°21′N; 62°13′W	St. Mary's R.	ES142	L&F	07	75	23.0	6.0	4.0	1.8	0.6	1,12,15
Mulgaman Lake	45°20′N; 61°56′W	Country Hbr. R.	ES122	DFO	07,08	76	29.0	5.6	9.3	3.0	1.4	1,2,4,12,18
Narrow Lake	45°24′N; 61°51′W	Salmon R.	ES29	DFO	08	73	25.5	6.4	27.0	11.0	5.1	1,3,4,7,10,18,26
Nickerson Lake	45°25′N; 61°33′W	Little L.	ES27	DFO	07	76	67.5	6.2	11.9	1.0	0.3	1,2,5,9
Northwest Arm Lake	45°12′N; 62°04′W	St. Mary's R.	ES142	L&F	09	79	18.5	5.5	17.5	2.0	1.3	Fished-No Success
Olson Lake	45°21′N; 61°57′W	Country Hbr. R.	ES122	DFO	06	76	43.0	6.0	13.4	5.5	1.6	1,2,4,5
Palmer Lake	45°18′N; 61°55′W	Country Hbr. R.	ES122	DFO	06	76	27.0	5.7	10.0	3.7	1.7	1,2,4,12,18,21
Pringle Lake	45°22′N; 61°57′W	Country Hbr. R.	ES122	DFO	07	73	39.8	6.1	62.7	26.0	9.8	1,2,3,4,10,17,18,26
Pye Lake	44°59′N; 62°06′W	Pye L.	ES160	L&F	07	81	66.0	6.0	11.6	8.6	2.2	2,4,5,15
Round Lake	45°25′N; 61°50′W	Salmon R.	ES29	DFO	08	73	23.4	6.8	46.5	7.6	2.9	1,2,4,10,12,13
Round Lake	45°24′N; 61°40′W	Salmon R.	ES29	DFO	08	76	40.0	7.1	9.4	7.0	2.1	1,2
Round Lake	45°11′N; 62°33′W	East R.	ES185	L&F	07	73	17.0	6.3	32.0	8.5	N/A	1,21
Rush Lake	45°12′N; 62°28′W	Liscomb R.	ES155	L&F	07	73	16.0	6.2	88.6	7.6	N/A	1,2,12,21
Second Lake	45°09′N; 61°56′W	Indian Hbr. R.	ES136	L&F	08	77	40.0	6.0	3.0	10.0	2.3	3,5,15
Second Rocky Lake	45°14′N; 62°33′W	East R.	ES185	L&F	07	73	12.0	6.0	51.0	4.6	N/A	1,2,21
Sherbrooke Lake	45°08′N; 61°58′W	St. Mary's R.	ES142	L&F	08	77	30.0	6.0	156.4	17.0	2.9	1,4,12,13,21
Simpsons Lake	45°27′N; 61°29′W	Clam Harbour R.	ES24	L&F	06	74	35.0	6.5	4.9	4.6	1.9	1,2,12
Sinclair Lake	45°05′N; 62°02′W	Liscomb R.	ES155	L&F	08	77	24.0	6.3	38.2	2.7	1.3	1,5,10,18
Smelt Lake	45°18′N; 61°11′W	Smelt L.	ES76	L&F	08	79	31.0	5.8	42.4	9.0	4.0	5
Smith lake	45°13′N; 62°09′W	Liscomb R.	ES155	L&F	09	79	19.4	5.5	5.8	1.0	0.9	1,2,12,21
Square Lake	45°16′N; 61°58′W	St. Mary's R.	ES142	DFO	06	76	30.0	6.3	5.0	3.7	1.6	1,4,18
Sullivan Lake	45°24′N; 61°53′W	South R.	NS48	DFO	05	76	21.0	6.8	6.2	2.0	1.0	2
Susies Lake	45°21′N; 61°41′W	Salmon R.	ES29	DFO	07	76	30.0	6.5	11.9	5.8	1.7	1,3,4,18,21
Third Lake	45°18′N; 61°13′W	Cole Harbour R.	ES82	L&F	09	77	36.0	6.0	92.0	16.0	4.6	2,3,5
Third Lake	45°09′N; 61°56′W	Indian Harbour R.	ES136	L&F	08	77	N/A	N/A	11.4	11.3	3.4	3,5,13,15
Three Mile Lake	45°20′N; 61°05′W	MacKenzie B.	ES50	L&F	07	74	60.0	6.0	55.1	13.7	3.3	2,5,15
Twin Lakes No.1	45°21′N; 62°15′W	St. Mary's R.	ES142	L&F	07	75	22.0	6.3	4.6	2.4	2.2	1,4,21
Unnamed Lake	44°58′N; 62°03′W	Unnamed L.	ES158	L&F	07	81	4212.0	7.3	9.1	5.0	1.9	3,5,15,17,30
Unnamed Lake	45°22′N; 61°56′W	Country Hbr. R.	ES122	DFO	06	77	18.0	6.5	7.3	3.0	1.3	2
Unnamed Lake	45°21′N; 61°58′W	South R.	NS48	DFO	07	77	22.0	6.7	4.9	6.0	2.8	1,2,4,7,12
Unnamed Lake	45°22′N; 61°58′W	Country Hbr. R.	ES122	DFO	07	77	55.0	7.0	7.1	4.0	1.3	1,2,3,12,18,21
Unnamed Lake	45°22′N; 61°56′W	Country Hbr. R.	ES122	DFO	06	77	22.0	5.5	3.5	1.5	1.1	Not fished
Upper Indian H. Lake	45°09′N; 61°56′W	Indian Harbour R.	ES136	L&F	07	76	73.0	6.7	11.3	12.8	4.6	2,3,5,15

		Watershed		Survey	Date		Conduct.		Surface	Depth		
Lake	Co-ordinates	Name	Code	Agency	Mo.	Yr.	(μmhos/cm)	pH	Area (ha)	Max.	Mean	Fish Species
Walsh Lake	45°27'N; 61°23'W	Collins P.	ES22	L&F	06	74	32.0	6.5	9.9	6.1	2.5	1,2,5,15
West River Lake	45°07'N; 63°15'W	Ecum Secum	ES165	L&F	08,09	78	23.0	6.5	24.8	4.0	1.8	5,14,15
Whidden Lake	45°14'N; 62°07'W	St. Mary's R.	ES142	L&F	08	78	31.0	6.3	48.0	3.0	1.6	15
Wilkins Lake	45°20'N; 61°04'W	Dover L.	ES51	L&F	07	74	50.0	6.5	33.8	13.7	9.6	2,3,5,15
Yankee Lake	45°08'N; 62°09'W	Liscomb R.	ES155	L&F	08	74	N/A	6.0	112.9	2.9	1.8	1,2,6,15,21
HALIFAX COUNTY												
Abraham Lake	44°47'N; 62°59'W	Abraham B.	ES221	L&F	06	75	56.0	6.6	16.7	6.6	2.3	1,2,3,5,12,15
Albro Lake	44°41'N; 63°35'W	None	ES285	DFO	07	71	66.0	6.5	23.6	21.0	N/A	2
Anderson Lake	44°43'N; 63°37'W	Wright B.	ES287	DFO	08	71	49.0	6.5	27.1	24.4	9.8	1,2
Antidam Flowage	45°07'N; 62°30'W	East R.	ES185	L&F	N/A	73	19.5	5.5	209.9	13.7	N/A	1,2,21
Baptizing Lake	44°43'N; 63°46'W	Nine Mile R.	SS29	DFO	07	74	51.3	5.5	30.7	6.0	2.7	1,2,10
Bare Rock Lake	44°48'N; 62°47'W	Newcombe B.	ES201	L&F	07	75	38.0	6.0	27.4	10.5	3.7	1,18
Barrett Lake	44°49'N; 63°41'W	Shubenacadie R.	MB92	L&F	07	79	14.5	6.8	3.7	6.0	2.8	13,21
Bayer Lake	44°49'N; 63°10'W	Musquodoboit R.	ES239	L&F	08	74	55.0	6.8	36.0	7.6	3.1	1,2,3,4,5,12,13,16,18,21
Bear Lake	45°02'N; 62°18'W	Moser R.	ES171	L&F	07	65	N/A	N/A	17.9	8.5	N/A	1,2,18
Bear Lake	44°57'N; 62°49'W	Tangier R.	ES198	L&F	09	73	42.0	6.4	63.1	15.2	N/A	3,4
Beaver Lake	44°45'N; 63°47'W	Sackville R.	SS1	DFO	08	78	50.0	5.0	17.0	4.0	1.5	4
Bell Lake	44°41'N; 63°31'W	Cow Bay P.	ES281	DFO	07	71	42.0	5.5	9.9	7.6	N/A	Fished-No Success
Big Indian Lake	44°36'N; 63°43'W	Prospect R.	SS26	DFO	06	72	42.0	5.5	106.0	8.5	3.4	2,5,10,12,15
Big Lake	44°31'N; 63°52'W	Black Duck R.	SS35	L&F	08	79	37.0	6.0	27.1	10.0	2.8	Fished-No Success
Bisset Lake	44°39'N; 63°28'W	Cow Bay P.	ES281	DFO	08	71	95.0	6.5	93.4	7.6	N/A	1,2,3,4
Bottle Lake	44°45'N; 63°46'W	Sackville R.	SS1	L&F	07	78	38.0	6.3	12.5	6.0	3.0	2
Bridgend Lake	44°47'N; 63°12'W	Chezzetcook R.	ES258	L&F	08	74	27.0	6.1	69.6	12.2	5.5	1,2,18
Brine Lake	44°37'N; 63°55'W	None	SS45	L&F	07	79	32.0	6.5	29.9	10.0	2.6	12
Burke Lake	45°06'N; 62°52'W	West R.	ES186	L&F	09	73	41.0	6.3	21.9	3.1	N/A	2,5
Camp Hill Lake	44°42'N; 63°49'W	Hosier R.	SS43	L&F	07	79	31.0	5.3	5.2	9.0	3.5	Fished-No Success
Catcha Lake	44°44'N; 63°12'W	Marie B.	ES252	L&F	04	81	46.0	7.3	6.0	2.2	1.6	2,5
Lake Charles	44°43'N; 63°33'W	Shubenacadie R.	MB92	DFO	07	71	67.0	6.0	144.1	28.4	N/A	1,3,4,9,27
Lake Charlotte	44°50'N; 62°58'W	Lake Charlotte	ES204	L&F	09	74	22.0	6.2	1485.7	51.2	11.4	1,2,3,5,10,12,15,18,21
Lake Chezzetcook	44°47'N; 63°14'W	Chezzetcook R.	ES258	L&F	09	74	28.0	5.9	244.9	18.3	4.3	1,2,3,5,12,18,21,26
Chocolate Lake	44°38'N; 63°38'W	Chocolate L.	SS4	DFO	08	71	370.0	6.3	10.1	11.4	N/A	1
Church Lake	44°57'N; 62°11'W	Church L.	ES167	L&F	06,07	81	61.0	6.3	13.4	11.3	3.1	2,10
Conrod Lake	44°46'N; 63°16'W	Chezzetcook R.	ES258	L&F	07	74	29.0	5.7	119.5	27.4	6.1	1,2,5,12,21

		Watershed		Survey	Date		Conduct.		Surface	Depth		
Lake	Co-ordinates	Name	Code	Agency	Mo.	Yr.	(μmhos/cm)	pH	Area (ha)	Max.	Mean	Fish Species
Coon Lake	44°56′N; 62°34′W	West R.	ES186	L&F	07	73	29.0	6.2	19.0	22.0	N/A	2
Copper Lake	44°48′N; 62°42′W	Rush L.	ES197	L&F	06	73	85.0	6.8	5.3	3.1	N/A	2
Cox Lake	44°43′N; 63°49′W	Nine Mile R.	SS29	DFO	07	74	51.7	6.6	109.3	14.0	5.0	1,2,3,18
Cranberry Lake	44°39′N; 63°46′W	Hosier R.	SS43	L&F	07	79	19.5	5.5	21.9	8.0	1.3	12
Cruickshank Lake	45°12′N; 62°34′W	East R.	ES185	L&F	06	73	22.0	6.3	4.5	2.4	N/A	1,2,12,21
Dog Lake	45°03′N; 62°21′W	Quoddy R.	ES176	L&F	N/A	N/A	N/A	N/A	14.6	5.5	N/A	Not Fished
Dollar Lake	44°55′N; 63°19′W	Musquodoboit R.	ES239	L&F	08	75	27.0	6.5	215.1	33.5	11.6	1,5,10
Dry lake	45°05′N; 63°02′W	Musquodoboit R.	ES239	L&F	04,05	81	62.0	7.5	17.5	1.0	0.5	1,2,4,6,12,21
Eastern Lake	44°31′N; 63°52′W	Eastern L.	SS34	L&F	08	79	58.0	5.5	6.4	8.0	2.2	Fished-No Success
Eagle Lake	44°45′N; 63°26′W	Partridge R.	ES265	L&F	08	74	39.0	5.7	88.6	11.7	5.0	1,2,5
Eagle Lake	44°58′N; 62°23′W	Salmon R.	ES179	L&F	08	81	25.7	6.5	61.8	7.0	2.6	1,3,5,15,20,21
East Lake	45°07′N; 62°35′W	East R.	ES185	L&F	07	73	16.0	6.4	30.4	4.6	N/A	1,2,4,6,12,21
East Pine Island Lake	44°35′N; 63°34′W	MacIntosh R.	SS8	L&F	08	79	43.0	5.0	6.8	9.0	2.6	Fished-No Success
Lake Echo	44°43′N; 63°23′W	Lawrencetown L.	ES265	L&F	08	79	26.0	5.5	218.2	10.0	2.1	1,2,4,10,12,13,31
Egg Lake	44°55′N; 62°53′W	Tangier R.	ES198	L&F	07	75	29.0	6.7	36.6	12.0	3.5	2,5,16
Elbow Lake	44°41′N; 63°50′W	East R.	SS49	L&F	07	79	52.0	6.0	9.7	2.0	1.1	Fished-No Success
Falls West Hill Lake	44°57′N; 62°32′W	West R.	ES186	L&F	07	73	19.0	5.7	15.0	3.7	N/A	1,2,12,21
Feely Lake	44°48′N; 63°42′W	Sackville R.	SS1	DFO	07	78	28.0	6.0	10.5	6.0	2.6	1,5
Ferry Lake	44°57′N; 62°46′W	Tangier R.	ES198	L&F	08	75	30.0	6.5	90.5	6.6	1.7	1,2,3,4,5,12,15,21
Fire Island Lake	44°39′N; 63°49′W	Hosier R.	SS43	L&F	07	79	50.0	6.0	133.5	11.0	3.4	12
First Lake	44°46′N; 62°59′W	Abraham B.	ES221	L&F	06	75	60.0	6.2	31.7	6.0	1.8	1,2,4,5
First Lake	44°46′N; 63°40′W	Shubenacadie R.	MB92	DFO	06	71	40.0	7.0	86.5	22.9	N/A	1,3,10
Fish Lake	44°46′N; 63°37′W	Shubenacadie R.	MB92	DFO	06	71	56.0	6.5	42.3	13.7	N/A	1,2,3,10,18
Fourth Lake	44°31′N; 63°43′W	McGrath B.	SS23	L&F	07	79	40.0	6.0	21.8	3.0	1.8	2
Fourth Lake	45°01′N; 62°25′W	Salmon R.	ES179	L&F	03	81	23.5	6.0	59.0	4.5	1.8	1,3,5,12,15,18,21
Fraser Lake (Little)	45°02′N; 62°38′W	East R.	ES185	L&F	07	73	19.0	6.3	6.1	3.1	N/A	1,2
Fraser Lake	44°40′N; 63°46′W	Nine Mile R.	SS29	DFO	07	74	48.9	6.3	66.8	20.0	8.3	1,2,18
Fraser Lake	44°35′N; 63°55′W	Fraser L.	SS42	L&F	07	79	35.0	6.3	12.5	14.0	5.9	2,3,5,12
Gaetz Lake	44°40′N; 63°16′W	Gaetz L.	ES26	L&F	07	74	88.0	6.7	24.5	3.1	0.8	3,5,18
Gammons Pond	44°55′N; 62°21′W	Gammons P.	ES177	L&F	N/A	73	67.0	6.3	7.7	7.6	N/A	4,5,6,15
Gammons Pond	44°55′N; 62°21′W	Gammons P.	ES177	L&F	07	81	79.0	6.0	7.5	10.0	2.8	2,5,12
Goose Lake	44°42′N; 63°20′W	Porters L.	ES264	L&F	09	74	36.0	6.7	44.4	9.1	2.6	1,2
Goose Pond	44°55′N; 62°20′W	None	ES175	L&F	07	72	N/A	N/A	8.1	6.1	3.7	2,3
Governor Lake	45°13′N; 62°40′W	East R.	ES185	L&F	08	73	16.7	6.4	651.6	12.8	N/A	1,2,3,4

Lake	Co-ordinates	Watershed Name	Code	Survey Agency	Date Mo.	Yr.	Conduct. (µmhos/cm)	pH	Surface Area (ha)	Depth Max.	Mean	Fish Species
Governor Lake	44°38′N; 63°42′W	Nine Mile R.	SS29	DFO	08	71	80.0	6.0	38.4	14.3	N/A	1,10,12
Grand Lake	44°55′N; 63°36′W	Shubenacadie R.	MB92	L&F	N/A	N/A	N/A	N/A	1821.0	36.0	N/A	Not Fished
Grand Lake	44°54′N; 63°09′W	Musquodoboit R.	ES239	L&F	07	78	46.0	6.5	99.5	30.0	9.3	1,10,21
Grand Lake	44°29′N; 63°38′W	Ocean R.	SS14	L&F	08	79	37.0	5.2	100.7	18.0	5.4	2
Grand Lake	44°55′N; 62°36′W	Grand L.	ES187	L&F	N/A	N/A	19.5	6.0	299.5	13.7	N/A	1,2,4,21
Grassy Lake	44°45′N; 62°57′W	Grassy L.	ES215	L&F	06	75	65.0	6.7	17.0	6.0	1.6	1,2,3,5,12,15
Grassy Lake	45°11′N; 62°33′W	East R.	ES185	L&F	06	73	18.0	6.5	26.0	7.6	N/A	1,2,21
Grassy Lake	44°44′N; 63°11′W	Chezzetcook R.	ES258	L&F	04,05	81	46.0	7.3	8.5	1.0	0.6	1,2
Green Lake	44°54′N; 62°25′W	Green L.	ES181	L&F	07	81	39.5	6.0	2.0	5.0	1.4	2,15
Grey Lake (Gray)	44°28′N; 63°38′W	Grey L.	SS15	L&F	08	79	44.0	5.0	7.2	9.0	3.3	Fished-No Success
Halfway Brook Lake	44°56′N; 62°27′W	Kirby R.	ES183	L&F	08	81	28.1	6.0	81.1	7.4	3.5	1,2,10,12,15
Halfway Lake	44°44′N; 63°47′W	Sackville R.	SS1	DFO	07	78	50.0	6.0	14.0	16.0	7.4	4
Harpell Pond	44°42′N; 63°01′W	Nine	ES229	L&F	07	78	12,700.0	8.5	1.6	2.0	1.0	Fished-No Success
Hartshorne Lake	45°06′N; 62°52′W	Musquodoboit R.	ES23	L&F	09	73	21.0	6.8	11.7	9.1	N/A	2,12,21
Hatchet Lake	44°34′N; 63°43′W	McGrath B.	SS23	L&F	07	79	58.0	6.5	68.3	22.0	7.4	5
Horseshoe Lake	44°54′N; 62°54′W	Tangier R.	ES198	L&F	07	75	N/A	6.6	25.9	8.4	1.4	1,3,4,5,12
Hubley Big Lake	44°39′N; 63°50′W	Hosier R.	SS43	L&F	08	79	34.0	6.0	255.3	14.0	3.0	2,5
Hubley Mill Lake	44°42′N; 63°52′W	East R.	SS49	L&F	07	79	64.0	6.2	20.2	8.0	2.9	1,2,5,12
Indian Lake	45°12′N; 62°38′W	East R.	ES185	L&F	06	76	12.0	5.8	26.3	3.1	N/A	2
Jonas Lake	44°54′N; 62°53′W	Tangier R.	ES198	L&F	07	75	29.0	6.8	18.8	8.4	2.3	1,3,4,21
Kearney Lake	44°42′N; 63°42′W	Paper Mill L.	SS3	DFO	06,07 09	71	30.0	6.0	51.0	26.2	N/A	1,2,12,21
Kelly Lake	45°03′N; 62°20′W	Moser R.	ES171	L&F	N/A	N/A	N/A	N/A	53.8	9.8	3.2	Not fished
Kidston Lake	44°36′N; 63°37′W	MacIntosh R.	SS8	DFO	09	71	28.0	5.5	10.7	5.5	N/A	Fished-No Success
Kindervator Lake	45°03′N; 62°18′W	Moser R.	ES171	L&F	07	65	N/A	N/A	20.2	23.0	N/A	1,18
Lawrencetown Lake	44°40′N; 63°22′W	Lawrencetown L.	ES265	L&F	08	74	110.0	7.2	402.3	1.5	0.7	1,3,5,12,15,18,23
Leader Lake	44°44′N; 63°03′W	Leader L.	ES228	L&F	07	74	45.0	5.5	25.6	10.1	2.3	2,5,12,15,18
Lewis Lake	44°49′N; 63°47′W	Sackville R.	SS1	DFO	07	78	60.0	6.0	21.0	2.0	0.9	1,4,12
Lewis Lake	44°45′N; 63°23′W	Partridge R.	ES265	L&F	07	78	37.0	6.3	7.8	3.7	1.3	1,3,13,21
Lewis Lake	44°41′N; 63°51′W	East R.	SS49	L&F	07	79	60.0	6.5	24.6	13.0	5.3	1,3,5,12
Lily Lake	44°52′N; 62°26′W	Lily L.	ES182	L&F	07	81	832.0	5.5	5.5	4.0	0.1	2,5,10
Lily Pond Lake	44°48′N; 62°47′W	Newcombe B.	ES201	L&F	06	75	57.0	6.0	26.7	6.0	1.2	1,5,12,18,21
Little Beaver Lake	44°58′N; 62°28′W	Kirby R.	ES183	L&F	08	81	26.7	5.5	12.0	2.2	1.4	1,2,10,12,15,21
Little Lake	44°29′N; 63°43′W	Little L.	SS22	L&F	07	79	32.0	6.0	4.8	8.0	3.7	Fished-No Success

Lake	Co-ordinates	Watershed Name	Watershed Code	Survey Agency	Date Mo.	Date Yr.	Conduct. (μmhos/cm)	pH	Surface Area (ha)	Depth Max.	Depth Mean	Fish Species
Little Lake	44°45′N; 63°16′W	Little L.	ES259	L&F	09	74	39.0	6.7	11.3	2.4	0.9	1,2,3,5,21
Little Springfield	44°48′N; 63°45′W	Sackville R.	SS1	DFO	07	78	340.0	4.5	8.0	7.0	3.4	Fished-No Success
Long Lake	44°30′N; 63°53′W	Long L.	SS37	L&F	08	79	91.0	5.5	3.6	7.0	2.6	Fished-No Success
Long Lake	44°38′N; 63°51′W	Hosier R.	SS43	L&F	09	79	32.0	6.3	61.9	7.0	2.5	2
Long Lake	44°37′N; 63°38′W	MacIntosh R.	SS8	DFO	08	71	40.0	5.5	171.0	30.2	N/A	2
Loon Lake	44°42′N; 63°30′W	Shubenacadie R.	MB92	DFO	07	71	68.0	6.5	75.7	6.1	2.6	1,2
Loon Lake	44°32′N; 63°43′W	McGrath B.	SS23	L&F	07	79	40.0	5.2	8.0	1.0	0.9	2
Loon Pond	44°56′N; 62°52′W	Lake Charlotte	ES204	L&F	07	80	18.5	7.3	28.4	19.7	7.2	2,6
Lower Beaver Lake	45°01′N; 62°46′W	West R.	ES186	L&F	07	73	N/A	6.0	29.1	7.6	N/A	1,4,12,21
Martin Lake	44°44′N; 63°24′W	Lawrenctown L.	ES265	L&F	08	74	35.0	5.5	19.1	9.1	2.9	1,2,5,10,18,21
Maynard Lake	44°40′N; 63°33′W	Sullivan P.	ES284	DFO	07	71	320.0	7.5	7.7	14.3	N/A	2,4,27
McGarth Lake	44°33′N; 63°43′W	McGrath B.	SS23	L&F	07	79	42.0	5.5	59.8	9.0	3.2	2,5,12
Meisner Lake	44°41′N; 63°12′W	Meisner L.	ES253	L&F	09	74	220.0	7.1	53.6	3.1	1.6	3,5,10
Micmac Lake	44°41′N; 63°33′W	Sullivan P.	ES284	DFO	07	71	98.0	7.0	109.0	6.1	N/A	1,3,27
Mill Lake	45°08′N; 62°54′W	Musquodoboit R.	ES239	L&F	09	73	17.0	6.7	108.5	15.2	N/A	1,2
Moody Lake	44°32′N; 63°39′W	Ocean R.	SS14	L&F	08	79	34.0	5.3	57.8	11.0	2.7	2
Moosehorn Lake	44°32′N; 63°43′W	McGrath B.	SS23	L&F	07	79	41.0	5.8	27.5	4.0	2.0	2,12
Morris Lake	44°39′N; 63°30′W	Cow Bay P.	ES281	DFO	08	71	125.0	6.5	175.9	12.8	N/A	1,3,5,10
Mushaboom Lake	44°53′N; 62°36′W	Mushaboom L.	ES189	L&F	N/A	73	32.0	5.5	130.3	10.7	N/A	4
Muskrat Lake	44°46′N; 62°57′W	Grassy L.	ES215	L&F	06	75	85.0	6.8	12.6	3.0	1.0	1,2,3,5
Muskrat Lake	44°57′N; 62°27′W	Kirby R.	ES183	L&F	08	81	N/A	N/A	44.8	4.0	1.8	1,2,10,21
Newcombe Lake	44°48′N; 62°48′W	Newcombe B.	ES201	L&F	08	75	35.0	6.0	70.3	8.1	2.5	1,2,5,18
Nowlin Lake	44°59′N; 62°22′W	Salmon R.	ES179	L&F	07	81	27.0	6.5	58.1	16.0	6.2	1,2,3
Oat Hill Lake	44°40′N; 63°33′W	Sullivan P.	ES284	DFO	08	71	255.0	6.5	4.7	8.5	N/A	27
Otter Lake	44°38′N; 63°44′W	Prospect R.	SS26	DFO	08	71	20.0	5.5	63.9	11.9	N/A	12
Otter Lake	44°03′N; 62°33′W	East R.	ES185	L&F	08	73	12.0	5.8	3.2	4.6	N/A	1,2,3,4,6,10,12
Otter Lake	44°55′N; 62°52′W	Tangier R.	ES198	L&F	07	75	29.0	6.4	27.2	12.0	3.8	1,2
Otter Lake	44°46′N; 63°24′W	Partridge R.	ES265	L&F	07	78	33.0	6.0	5.0	12.0	2.7	1,2,6
Oyster Pond	44°47′N; 63°00′W	Oyster P.	ES222	L&F	09	74	15100.0	7.2	50.9	7.6	3.0	2,10
Pace Lake	44°49′N; 63°13′W	Little R.	ES250	L&F	09	74	32.0	6.2	302.7	51.2	13.7	3,5,12
Paper Mill Lake	44°43′N; 63°41′W	Paper Mill L.	SS3	DFO	09	71	33.0	6.5	23.5	6.1	N/A	1,2,10
Paterson Lake	44°31′N; 63°53′W	Black Duck R.	SS35	L&F	08	79	46.0	5.0	22.1	7.0	3.3	1,21
Paul Morris Lake	44°57′N; 62°22′W	Quoddy R.	ES176	L&F	07	81	32.2	6.0	11.5	11.7	5.1	1,3,5,6,10,12
Pearl Lake	44°51′N; 62°55′W	Little R.	ES203	L&F	07	80	22.6	6.5	11.1	7.1	2.5	2

Lake	Co-ordinates	Watershed Name	Code	Survey Agency	Date Mo.	Yr.	Conduct. (μmhos/cm)	pH	Surface Area (ha)	Depth Max.	Mean	Fish Species
Penhorn Lake	44°40′N; 63°33′W	Cow Bay P.	ES281	DFO	07	71	320.0	6.5	4.0	8.8	N/A	Fished-No Success
Petpeswick Lake	44°45′N; 63°11′W	Chezzetcook R.	ES258	L&F	08	74	35.0	6.8	256.8	19.8	4.9	1,2,3,5,18,21
Philip Lake	44°56′N; 62°50′W	Lake Charlotte	ES204	L&F	06	75	27.0	6.6	19.8	11.1	2.9	1,3,12,21
Porters Lake	44°45′N; 63°18′W	Porters L.	ES264	DFO	07	67	N/A	N/A	1651.1	30.5	N/A	3,17,18,24,25,30
Porters Lake	44°45′N; 63°18′W	Porters L.	ES264	DFO	08	67	N/A	N/A	1651.1	30.5	N/A	2,5,10,12,32,33
Porters Lake	44°45′N; 63°18′W	Porters L.	ES264	DFO	09	67	N/A	N/A	1651.1	30.5	N/A	1,34,35,36
Portuguese Lake	44°31′N; 63°33′W	None	SS12	L&F	08	79	38.0	5.5	17.8	5.0	2.3	2
Pot Lake	44°54′N; 63°10′W	Musquodoboit R.	ES239	L&F	07	78	34.0	6.5	11.3	3.0	2.4	1,21
Power Pond	44°35′N; 63°33′W	McIntosh R.	SS8	L&F	08	79	61.0	5.5	9.7	9.0	3.3	Fished-No Success
Pug Hole Lake	44°51′N; 62°55′W	Little R.	ES203	L&F	07	80	22.0	6.5	10.0	8.0	3.5	2,10
Quoddy Lake	45°01′N; 62°20′W	Quoddy R.	ES176	L&F	08	81	26.0	6.0	15.6	5.0	1.5	1,5,6,12,15,18
River Lake	44°55′N; 62°45′W	Tangier R.	ES198	L&F	09	73	21.5	5.2	102.0	12.2	N/A	1,3,4,8,12,21
River Lake	45°01′N; 62°45′W	West R.	ES186	L&F	07	73	13.8	5.5	82.6	10.7	N/A	1,4,10,12,21
Round Lake	45°04′N; 62°20′W	Moser R.	ES171	L&F	07	81	22.4	5.5	49.8	8.0	3.6	1,2,10,12,18,21
Run Lake	44°33′N; 63°39′W	Ocean R.	SS14	L&F	08	79	36.0	5.0	14.5	5.0	1.4	Fished-No Success
Russel Lake	44°40′N; 63°32′W	Cow Bay P.	ES281	DFO	09	70	198.0	7.0	34.4	9.1	N/A	1,3,4,10,12
Salmon River Big L.	44°59′N; 62°25′W	Salmon R.	ES179	L&F	08	81	22.4	6.0	269.9	2.0	1.2	1,3,12,21
Sandy Lake	44°44′N; 63°42′W	Sackville R.	SS1	DFO	07	71	37.0	6.0	81.8	19.2	N/A	1,2,4,5,10
Scott Lake	44°32′N; 63°52′W	Scott L.	SS33	DFO	N/A	N/A	N/A	5.4	15.0	5.2	N/A	2,12
Scraggy Lake	44°57′N; 62°53′W	Lake Charlotte	ES204	L&F	07	75	23.0	6.6	644.5	12.6	3.3	1,2,3,5,6,10,12,18,21
Second Lake	44°47′N; 63°39′W	Shubenacadie R.	MB92	DFO	10	71	32.0	7.0	123.6	12.2	N/A	1,3,4,10,12,21,27
Seventeen Mile L.	45°11′N; 62°33′W	East R.	ES185	L&F	07	73	17.0	6.2	16.2	7.0	N/A	1,2,21
Sheehan Lake	44°30′N; 63°38′W	Ocean R.	SS14	L&F	08	79	40.0	5.0	28.3	10.0	3.2	2
Sheldrake Lake	44°40′N; 63°48′W	Hosier R.	SS43	L&F	07	79	55.0	5.8	12.9	7.0	2.8	12
Sloane Lake	45°10′N; 62°30′W	East R.	ES185	L&F	08	74	15.0	6.2	291.4	12.2	N/A	1,2,12,21
Snow Lake	44°41′N; 63°20′W	Porters L.	ES264	L&F	09	74	60.0	6.6	38.1	4.6	1.9	1,2,3,4,5,12
Southwest Lake	44°58′N; 62°43′W	West R.	ES186	L&F	08	75	30.0	6.7	203.1	15.6	5.7	1,2,3,4,5,12
Spruce Hill Lake	44°35′N; 63°39′W	Grand L.	SS14	DFO	09	71	22.0	6.0	102.1	12.8	N/A	2
Stillwater Lake	44°43′N; 63°51′W	East R.	SS49	L&F	08	79	39.0	6.0	50.5	17.0	4.5	1,12
Susies & Quarry Lake	44°40′N; 63°42′W	Paper Mill L.	SS3	DFO	07	72	38.0	5.7	139.2	9.1	N/A	1,2,4
Tangier Lake	44°50′N; 62°44′W	Tangier R.	ES198	L&F	07	75	27.0	6.2	164.5	10.5	2.6	1,4,5,10,18,21
Taylor Bay Grand L.	44°55′N; 62°42′W	Bay B.	ES191	L&F	08	75	31.0	6.2	136.8	13.2	3.3	1,2,4,5,12
Third Lake	44°51′N; 62′41′W	Tangier R.	ES198	L&F	06	73	23.5	6.0	50.2	27.4	N/A	1,2,3,4,12,18,21
Third Lake	44°47′N; 63°38′W	Shubenacadie R.	MB92	DFO	06,10	71	45.0	6.5	84.8	24.4	N/A	1,3,4,10,27

Lake	Co-ordinates	Watershed		Survey	Date		Conduct.		Surface	Depth		
		Name	Code	Agency	Mo.	Yr.	(μmhos/cm)	pH	Area (ha)	Max.	Mean	Fish Species
Three Mile Lake	44°49′N; 63°30′W	Little Salmon R.	ES274	DFO	06	71	45.0	6.5	19.9	11.3	N/A	1,3
Tomahawk Lake	44°47′N; 63°48′W	Sackville R.	SS1	DFO	07	78	28.0	6.0	124.5	9.3	3.8	1,4
Unnamed Lake	44°47′N; 63°09′W	Musquodoboit R.	ES239	L&F	09	74	37.0	5.4	4.4	6.1	2.3	4
Unnamed Lake	44°52′N; 62°26′W	Kirby R.	ES183	L&F	07	81	1664.0	6.0	7.9	1.6	0.8	1,2,3,5
Unnamed Lake	44°55′N; 62°21′W	Unnamed L.	N/A	L&F	08	81	2958.0	7.5	3.8	4.0	1.5	4,5,15
Unnamed Lake	44°55′N; 62°22′W	Unnamed L.	ES178	L&F	08	81	54.0	5.0	1.3	2.0	1.0	Fished-No Success
Unnamed Lake	44°44′N; 62°50′W	Unnamed L.	ES209	L&F	08	81	70.4	5.5	7.3	1.0	0.9	Fished-No Success
Weaver Lake - North	44°35′N; 63°38′W	Ocean R.	SS14	L&F	08	79	183.0	7.5	2.8	3.0	0.9	Not fished
Weaver Lake - South	44°35′N; 63°38′W	Ocean R.	SS14	L&F	08	79	104.0	6.0	2.0	2.0	0.7	Not fished
Webber Lake	44°47′N; 63°44′W	Sackville R.	SS1	DFO	10	71	40.0	6.0	39.1	16.8	N/A	1,2,10
Weeks Lake	44°48′N; 62°54′W	Lake Charlotte	ES204	L&F	08	75	36.0	6.6	622.0	7.5	1.5	1,2,3,5,12,18,21
Welsh Lake	44°32′N; 63°49′W	Welsh L.	SS30	L&F	08	79	38.0	5.0	15.3	3.0	1.7	12
Whites Lake	44°32′N; 63°45′W	Prospect R.	SS26	L&F	07	79	38.0	6.0	43.7	11.0	3.7	2,10
William Lake	44°46′N; 63°35′W	Shubenacadie R.	MB92	DFO	08	71	28.0	7.5	323.8	28.4	N/A	1,3,27
Williams Lake	44°37′N; 63°36′W	Williams L.	SS6	DFO	09,10	71	600.0	6.5	39.6	19.8	N/A	2,5
Williams Lake	44°43′N; 63°03′W	Oyster P.	ES231	L&F	07	74	40.0	6.1	49.6	1.5	0.6	3,5,12,18
HANTS COUNTY												
Armstrong Lake	44°50′N; 64°12′W	Avon R.	MB54	L&F	07	77	40.0	N/A	52.0	7.3	6.8	1,2,6
Cockscomb Lake	44°56′N; 63°51′W	Avon R.	MB54	DFO	07	78	29.0	6.3	144.0	33.0	11.5	1,2,4,12
Cockscomb Lake	44°56′N; 63°51′W	Avon R.	MB54	L&F	07	75	N/A	N/A	164.8	30.5	N/A	1,2,4
Falls Lake	44°51′N; 64°15′W	Avon R.	MB54	L&F	08	77	27.0	5.8	98.0	12.0	3.5	1,6,21
Little Island Lake	44°49′N; 64°19′W	Avon R.	MB54	L&F	08	77	25.0	6.0	19.0	6.7	2.5	1,5,15
Lower Canoe Lake	44°49′N; 64°19′W	Avon R.	MB54	L&F	08	77	25.0	6.0	87.5	11.2	3.5	1,5,15
Mockingigh Lake	44°50′N; 64°14′W	Avon R.	MB54	L&F	08	77	31.0	N/A	109.3	10.0	5.7	1,5
Noel Lake	44°16′N; 63°44′W	Noel R.	MB80	L&F	07	79	172.0	7.5	118.5	2.0	1.3	1,4,12,21
Panuke Lake	44°48′N; 64°07′W	Avon R.	MB54	L&F	07	73	76.0	5.5	313.6	34.8	N/A	1,2,4,10,21
Pentz Lake	44°53′N; 63°49′W	Sackville R.	SS1	DFO	07	78	58.0	6.0	36.5	5.0	2.5	1,2,3,4,12
Pigott Lake	44°56′N; 63°53′W	Avon R.	MB54	L&F	07	81	430.0	7.5	90.5	17.0	5.7	1,4,5,6,10,12
Valley Lake	45°03′N; 63°46′W	Avon R.	MB54	L&F	N/A	N/A	N/A	N/A	22.3	8.2	4.3	Not fished
Zwicker Lake	44°49′N; 64°14′W	Avon R.	MB54	L&F	08	77	26.0	6.5	56.9	15.0	4.9	1,5,6
INVERNESS COUNTY												
Lake Ainslie	46°08′N; 61°11′W	Margaree R.	CBW44	L&F	06,08	78	105.0	7.8	5735.8	18.0	5.7	2,3,5,15,16,18

		Watershed		Survey	Date		Conduct.		Surface	Depth		
Lake	Co-ordinates	Name	Code	Agency	Mo.	Yr.	(μmhos/cm)	pH	Area (ha)	Max.	Mean	Fish Species
Grand Lac	46°33′N; 61°01′W	Ruis du Lac	CBW38	L&F	08	75	200.0	8.0	29.3	8.1	3.4	1,3,10,15,18
Horton Lake	45°41′N; 61°23′W	Horton B.	CBW115	L&F	08	74	N/A	6.8	47.2	6.1	3.0	1,2,12,17,18
Lake O'Law	46°17′N; 60°58′W	Margaree R.	CBW44	L&F	09	76	35.0	7.5	27.1	30.0	9.3	1,2,15
MacIntyre Lake	45°39′N; 61°17′W	Little R.	CBC306	L&F	08	74	N/A	6.3	46.0	9.1	3.5	1,2,3,5
Pembroke Lake	46°30′N; 60°59′W	Grand Etang B.	CBW39	L&F	08	78	56.0	6.6	55.0	10.0	N/A	2,5
Petit Lake	46°33′N; 61°03′W	Grand Etang B.	CBW39	L&F	08	75	360.0	8.1	9.1	15.0	4.9	1,5
Presqu'ile Lake	46°41′N; 60°58′W	Presqu'ile B.	CBW32	CWS	06	47	274.0	7.8	4.4	3.0	2.1	17
KINGS COUNTY												
Armstrong Lake	44°46′N; 64°44′W	La Have R.	SS95	L&F	08	76	32.0	6.5	94.7	5.7	3.1	1,5,6,12,15,21
Aylesford Lake	44°57′N; 64°40′W	Gaspereau R.	MB53	L&F	06	78	34.0	6.5	532.0	12.0	5.1	1,2,3,4,21
Birch Lake	44°53′N; 64°51′W	Annapolis R.	FA124	L&F	07	76	32.0	6.5	27.5	12.0	3.5	1,4,5,21
Black Duck Lake	44°43′N; 64°43′W	La Have R.	SS95	L&F	07	78	32.0	6.5	61.9	3.0	2.0	1,2,5,12,20,21
Black River Lake	44°56′N; 64°24′W	Gaspereau R.	MB53	L&F	07	78	N/A	5.9	766.9	12.0	3.5	1,3,21
Boot Lake	44°53′N; 64°46′W	Annapolis R.	FA124	L&F	08	67	N/A	N/A	14.5	7.6	3.3	4
Boot Lake	44°53′N; 64°46′W	Annapolis R.	FA124	L&F	09	81	23.5	6.0	17.6	6.2	2.5	1,4,12,21
Burke Lake	44°44′N; 64°42′W	La Have R.	SS95	L&F	07	68	N/A	N/A	17.6	9.0	4.6	2
Burke Lake	44°44′N; 64°42′W	La Have R.	SS05	L&F	06	81	23.9	7.5	18.4	9.0	4.3	1,2,4,5,12
Chain Lake	44°48′N; 64°45′W	La Have R.	SS95	L&F	09	76	33.0	6.4	80.7	3.0	1.6	1,2,5,6,12,15,21
Cloud Lake	44°52′N; 64°53′W	La Have R.	SS95	L&F	08	78	39.0	6.4	176.5	16.0	5.6	1,4
Colwell Round Lake	44°51′N; 64°36′W	La Have R.	SS95	L&F	08	78	N/A	6.5	13.8	2.0	1.4	1,4,12,21
Colwell Lake	44°51′N; 64°35′W	Gaspereau R.	MB53	L&F	08	78	N/A	6.3	23.1	4.0	2.2	1,4,12,21
East Twin Lake	44°47′N; 64°48′W	La Have R.	SS95	L&F	08	78	31.0	4.8	12.1	12.0	4.6	2,5,10,12,15,21
Ell Lake	44°44′N; 64°47′W	La Have R.	SS95	L&F	08	78	30.0	5.8	21.1	2.0	1.6	2,10,21
Fox Lake	44°52′N; 64°49′W	Annapolis R.	FA124	L&F	08	78	30.0	5.5	18.2	11.0	2.2	2,4,5
Frog L. (LaHave L.)	44°50′N; 64°51′W	La Have R.	SS95	L&F	08	78	36.0	6.3	211.3	14.0	1.8	1,2,4,21
Lake George	44°56′N; 64°42′W	La Have R.	SS95	L&F	06	78	40.0	6.5	153.0	9.0	4.8	1,4,5,21,27
Hardwood Lake	44°51′N; 64°39′W	La Have R.	SS95	L&F	06	78	34.0	6.5	119.8	7.0	4.1	1,4,5,6,10,12,21
Hudson Lake	44°53′N; 64°32′W	Gaspereau R.	MB53	L&F	06	80	36.0	6.5	2.8	2.0	1.1	1,4,10,12,21
Lakeville Lake	45°07′N; 64°36′W	Cornwallis R.	MB50	L&F	06	78	N/A	6.7	3.2	14.3	3.8	15
Loon Lake	44°54′N; 64°40′W	Gaspereau R.	MB53	L&F	06	78	33.0	6.3	69.6	6.0	3.5	1,3,4,12,21
Mack Lake	44°42′N; 64°46′W	La Have R.	SS95	L&F	07	78	30.0	5.5	70.4	6.0	1.8	1,2,5,21
Midconner Lake	44°51′N; 64°44′W	La Have R.	SS95	L&F	07	68	N/A	N/A	4.5	5.8	3.7	Not fished
Midconner Lake	44°51′N; 64°44′W	La Have R.	SS95	L&F	07,09	81	26.2	7.5	3.9	6.0	3.1	1,2,4,13,21

Lake	Co-ordinates	Watershed		Survey	Date		Conduct.	pH	Surface	Depth		Fish Species
		Name	Code	Agency	Mo.	Yr.	(µmhos/cm)		Area (ha)	Max.	Mean	
Mistake Lake	44°49'N; 64°49'W	La Have R.	SS95	L&F	08	76	31.0	6.0	18.6	6.7	2.4	1,2,4,5,12,21
Murphy Lake	44°54'N; 64°31'W	Gaspereau R.	MB53	L&F	N/A	N/A	N/A	N/A	118.8	3.0	2.0	Not fished
Murphy Lake	44°54'N; 64°31'W	Gaspereau R.	MB53	L&F	08	81	41.3	7.0	120.9	3.2	1.9	4
Nimchin Page Lae	44°48'N; 64°42'W	La Have R.	SS95	L&F	09	76	28.0	6.6	106.8	5.2	2.4	1,2,6,12,15,20,21
North Twin Lake	44°52'N; 64°43'W	La Have R.	SS95	L&F	07	68	N/A	N/A	22.7	N/A	3.1	1,2
North Twin Lake	44°52'N; 64°43'W	La Have R.	SS95	L&F	09	81	27.5	6.5	17.8	6.0	2.6	1,2,21
Oak Lake	44°52'N; 64°46'W	La Have R.	SS95	L&F	08	67	N/A	N/A	20.2	N/A	2.3	1,2,21
Oak Lake	44°52'N; 64°46'W	La Have R.	SS95	L&F	09	81	23.0	6.5	16.0	5.0	1.7	1,2,20,21
Otter Lake	44°43'N; 64°45'W	La Have R.	SS95	L&F	07	78	30.0	6.2	28.3	3.0	1.1	1,2,5,6,10,12,21
Parker Lake	44°54'N; 64°44'W	Annapolis R.	FA124	L&F	07	78	32.0	6.4	193.9	12.0	2.3	1,4,21
Parker Lake	44°54'N; 64°44'W	Annapolis R.	FA124	L&F	07	81	27.5	6.4	193.9	12.0	2.3	1,4,12,21
Lake Paul	44°52'N; 64°42'W	La Have R.	SS95	L&F	08	76	36.0	7.0	119.8	6.0	2.7	1,4,5,12,21
Peter Lake	44°50'N; 64°49'W	La Have R.	SS95	L&F	08	76	28.0	6.5	18.2	6.0	1.5	Not fished
Randalls Lake	44°54'N; 64°50'W	Annapolis R.	FA124	L&F	07	78	30.0	6.4	92.3	8.0	2.6	1,4,21
Shell Camp Lake	44°50'N; 64°48'W	La Have R.	SS95	L&F	07	78	29.0	5.4	200.4	8.0	3.1	1,4,5,21
South Twin Lake	44°51'N; 64°43'W	La Have R.	SS95	L&F	07	68	N/A	N/A	22.4	9.0	4.3	Not fished
South Twin Lake	44°51'N; 64°43'W	La Have R.	SS95	L&F	07	81	25.0	6.5	18.6	10.0	2.9	1,2,21
Sunken Lake	45°00'N; 64°27'W	Gaspereau R.	MB53	L&F	06	81	37.7	7.4	28.5	6.0	2.5	5,8,15,21
Tener Lake	44°45'N; 64°47'W	La Have R.	SS95	L&F	07	78	36.0	N/A	12.6	1.2	0.8	2,5,12,21
Tomahawk Lake	44°53'N; 64°45'W	La Have R.	SS95	L&F	08	67	N/A	N/A	17.9	N/A	1.8	1,2,21
Lake Torment	44°44'N; 64°44'W	La Have R.	SS95	L&F	06	78	34.0	6.3	278.1	8.0	2.3	1,5,6,12,21
Turbot Lake	44°50'N; 64°32'W	Gaspereau R.	MB53	L&F	07	78	N/A	6.7	13.4	2.0	1.1	4,12,21
Upper Palmer Lake	44°53'N; 64°47'W	Annapolis R.	FA124	L&F	07	78	32.0	5.8	14.1	2.0	1.1	1,4,10,21
Upper Sixty Lake	44°46'N; 64°49'W	La Have R.	SS95	L&F	08	76	28.0	5.8	61.5	3.0	1.5	2,5,10,12,21
West Twin Lake	44°47'N; 64°48'W	La Have R.	SS95	L&F	07	78	27.0	6.2	13.0	1.5	1.2	2,12,15,21
LUNENBURG COUNTY												
Awalt Lake	44°31'N; 64°02'W	Awalt Lake B.	SS62	DFO	09	72	N/A	5.0	9.6	13.7	3.1	Fished-No Success
Becks Lake	44°21'N; 64°25'W	LaHave R.	SS95	L&F	07,08	68	N/A	N/A	15.1	11.3	4.6	Fished-No Success
Bezanson Lake	44°38'N; 64°16'W	Middle R.	SS73	L&F	08	64	N/A	N/A	123.3	14.9	N/A	1,4,21
Big Mushamush Lake	44°30'N; 64°33'W	Mushamush R.	SS81	L&F	09	80	N/A	7.5	1088.7	25.0	8.1	1,3,4,18,21
Butler Lake	44°43'N; 64°41'W	LaHave R.	SS95	L&F	06	65	N/A	N/A	68.4	5.5	N/A	1,2,12,21
Camp Lake	44°48'N; 64°27'W	Gold R.	SS75	L&F	06	80	19.5	7.0	20.9	5.0	2.3	1,2,4,5,6,12,13,21
Canoran Lake	44°36'N; 64°34'W	Mushamush R.	SS81	L&F	08	80	27.0	7.5	16.7	10.0	3.2	1,2,3,4,6,12,21

		Watershed		Survey	Date		Conduct.		Surface	Depth		
Lake	Co-ordinates	Name	Code	Agency	Mo.	Yr.	(µmhos/cm)	pH	Area (ha)	Max.	Mean	Fish Species
Caribou Lake	44°32′N; 64°33′W	Mushamush R.	SS81	L&F	08	81	32.0	7.5	273.9	50.0	20.3	1,3,4,12,18
Church Lake	44°33′N; 64°36′W	LaHave R.	SS95	L&F	08	80	23.5	7.0	93.3	0.6	0.4	1,3,4,5,6,12,13,21
Cornwall Lake	44°32′N; 64°34′W	Mushamush R.	SS81	L&F	08	80	33.5	7.4	14.5	5.0	2.5	1,12
Cranberry Lake	44°40′N; 64°40′W	LaHave R.	SS95	L&F	08	80	23.5	6.3	22.1	2.6	1.1	1,2,12
Doreys Lake	44°36′N; 64°33′W	LaHave R.	SS95	L&F	08	80	23.5	7.0	19.8	4.8	2.6	1,4,12,21
Fox Point Lake	44°36′N; 64°05′W	Fox Point B.	SS58	DFO	09	78	35.0	5.6	137.5	19.0	4.9	2
Franey Lake	44°43′N; 64°40′W	LaHave R.	SS95	L&F	08	80	24.0	7.3	17.8	3.0	1.5	1,4,5,12
Frank Lake	44°31′N; 64°35′W	Mushamush R.	SS81	L&F	11	80	N/A	6.8	8.7	3.0	1.1	2,4,12,21
Harris Lake	44°47′N; 64°28′W	Gold R.	SS75	L&F	07	80	22.0	7.2	71.1	11.2	4.5	1,2,4,6,15,21
Hartling Pond	44°16′N; 64°16′W	None	SS90	L&F	N/A	N/A	N/A	N/A	12.6	6.7	4.6	Not fished
Holbert Lake	44°37′N; 64°34′W	LaHave R.	SS95	L&F	08	80	27.0	7.0	34.8	10.0	4.3	2,4,21
Horseshoe Lake	44°45′N; 64°26′W	Gold R.	SS75	L&F	07	80	27.0	7.0	46.2	4.0	1.9	1,2,5,15
Indian Lake	44°34′N; 64°38′W	LaHave R.	SS95	L&F	08	80	25.0	6.5	11.0	13.5	5.9	1,3,4,9,12,21
Indian Lake	44°47′N; 64°24′W	Gold R.	SS75	L&F	07	80	30.0	7.5	31.9	11.6	5.1	1,2,5,15,20
Lake Lewis	44°47′N; 64°23′W	Gold R.	SS75	L&F	07	80	22.5	6.3	75.3	12.0	3.8	1,4,12,21
Little Joe Long L.	44°46′N; 64°17′W	Avon R.	MB54	L&F	11	80	N/A	6.3	6.7	4.0	2.3	2,20,21
Mushamush Lake	44°31′N; 64°28′W	Mushamush R.	SS81	L&F	08	80	29.0	7.0	425.3	16.0	5.2	1,3,4,21,26
Nickersons Pond	44°04′N; 64°42′W	Nickersons P.	SS113	DFO	07	72	N/A	6.0	33.6	6.1	1.8	1,2,4
Pear Lake	44°37′N; 64°37′W	LaHave R.	SS95	L&F	06	79	31.0	7.0	12.9	8.0	3.0	1,4,5,6,12
Randall Lake	44°27′N; 64°31′W	LaHave R.	SS95	DFO	07	74	33.0	7.3	19.0	8.0	3.4	2
Romkey Pond	44°16′N; 64°17′W	None	SS91	L&F	N/A	N/A	N/A	N/A	17.6	4.6	2.4	Not fished
Seffern Lake	44°41′N; 64°25′W	Gold R.	SS75	L&F	09	80	37.0	6.0	6.1	1.0	0.9	Not fished
Sherbrooke Lake	44°40′N; 64°36′W	LaHave R.	SS95	L&F	05	73	N/A	N/A	1651.0	N/A	N/A	1,4,11,14,18
Spectacle Lake #1	44°23′N; 64°23′W	Lohnes B.	SS86	L&F	N/A	N/A	N/A	N/A	5.0	4.9	4.3	Not fished
Spectacle Lake #2	44°23′N; 64°23′W	Lohnes B.	SS86	L&F	N/A	N/A	N/A	N/A	5.0	4.3	3.4	Not fished
Steverman Lake	44°23′N; 64°20′W	Martin Cove R.	SS85	DFO	09	72	N/A	7.0	28.0	7.6	2.1	1,3,4,10,21,27
Texas Lake	44°36′N; 64°36′W	LaHave R.	SS95	L&F	08	80	22.5	6.5	11.6	2.0	1.0	1,2,4,6,9,12,20,21
Upper (So.) Canoe L.	44°47′N; 64°20′W	Falls L.	MB5	L&F	06	80	17.9	6.4	237.1	8.0	4.0	1,12,13
Wallaback Lake	44°49′N; 64°26′W	Gold R.	SS75	L&F	06	80	18.7	7.0	287.7	6.0	3.1	1,2,4,5,12,21
Whalen Lake	44°46′N; 64°25′W	Gold R.	SS75	L&F	08	72	N/A	N/A	22.3	3.1	2.7	Not fished
Whetstone Lake	44°40′N; 64°39′W	LaHave R.	SS95	L&F	07	80	23.0	7.0	55.3	5.0	2.9	1,2,5,6,12
Lake William	44°36′N; 64°39′W	LaHave R.	SS95	L&F	07	80	26.5	7.5	87.2	11.6	3.9	1,3,4,6,12,21

Lake	Co-ordinates	Watershed Name	Watershed Code	Survey Agency	Date Mo.	Date Yr.	Conduct. (µmhos/cm)	pH	Surface Area (ha)	Depth Max.	Depth Mean	Fish Species
PICTOU COUNTY												
Big Bear Lake	45°22′N; 62°17′W	St. Mary's R.	ES142	L&F	07	75	24.0	6.6	2.5	3.0	1.5	4
Black Lake	45°23′N; 62°41′W	East R.	NS145	L&F	08	75	28.0	6.8	6.8	3.0	2.2	1
Black Lake	45°24′N; 62°19′W	St. Mary's R.	ES142	L&F	06	75	N/A	N/A	4.2	5.7	N/A	1,2,4,5,15
Black Brook Lake	45°26′N; 62°10′W	St. Mary's R.	ES142	L&F	06	75	40.0	6.0	23.8	18.0	7.6	1,2,15
Burroughs Lake	45°27′N; 62°26′W	Sutherland R.	NS132	L&F	07	75	35.0	6.8	28.7	3.0	1.6	2,12
Burroughs Lake	45°27′N; 62°26′W	Sutherland R.	NS132	DFO	07	76	35.0	7.0	31.6	2.0	0.3	2,12
Campbell Lake	45°29′N; 62°25′W	French R.	NS126	L&F	07	75	54.0	7.0	2.8	7.5	2.1	2
Cranberry Lake	45°22′N; 62°17′W	St. Mary's R.	ES142	L&F	07	75	21.0	6.5	10.0	2.4	N/A	1,2,4,12
Dryden Lake	45°23′N; 62°47′W	Middle R.	NS152	L&F	08	75	30.0	6.8	7.9	2.4	1.9	1,4,12
Eden Lake	45°24′N; 62°18′W	St. Mary's R.	ES142	L&F	06	75	37.0	6.5	181.7	16.5	7.8	1,2,4,9,18,26
Elbow Lake	45°22′N; 62°14′W	St. Mary's R.	ES142	L&F	07	75	N/A	6.5	13.7	2.4	1.7	2,12
Gairloch Lake	45°29′N; 62°50′W	Middle R.	NS152	L&F	08	75	55.0	7.5	4.7	4.5	2.4	1,2,10,16
Gait Pond	45°41′N; 62°19′W	Gait P.	NS114	L&F	06	75	N/A	9.0	14.3	2.4	1.5	15,18
Grant Lake	45°26′N; 62°39′W	East R.	NS145	L&F	07	75	43.0	6.9	22.7	9.0	3.1	1,2,5,12,21
Gunn Lake	45°25′N; 62°11′W	St. Mary's R.	ES142	L&F	06	75	40.0	6.4	5.2	6.0	2.6	1,2,15
Little Bear lake	45°22′N; 62°16′W	St. Mary's R.	ES142	L&F	07	75	24.0	6.0	2.6	1.5	1.0	4
McKinnon Lake	45°22′N; 62°32′W	St. Mary's R.	ES142	L&F	08	75	24.0	6.2	30.9	3.6	2.0	1,2,4,5,12
MacPhersons Lake	45°28′N; 62°33′W	East R.	NS145	L&F	07	75	37.0	7.0	13.4	3.0	2.3	2,6,10
Mill Pond	45°26′N; 62°49′W	Middle R.	NS152	L&F	08	75	52.0	7.3	3.7	5.1	3.0	1,2,10
Milldam Lake	45°23′N; 62°17′W	St. Mary's R.	ES142	L&F	07	75	22.0	6.0	10.2	10.5	4.9	4
Normans Lake	45°26′N; 62°26′W	East R.	NS145	L&F	07	75	29.0	6.4	16.8	7.5	3.3	1,2,5,12,14
Otter Lake	45°41′N; 62°36′W	Otter P.	NS141	L&F	08	75	N/A	7.0	6.3	3.0	2.0	1,3,4,12
Perch Lake	45°21′N; 62°37′W	St. Mary's R.	ES142	L&F	07	75	N/A	6.8	22.8	4.2	2.0	1,2,4,12
Pictou Causeway Pd.	45°40′N; 62°44′W	Haliburton B.	NS152	L&F	08	80	N/A	6.0	401.0	8.0	N/A	1,3,18,23
Pictou Causeway Pd.	45°40′N; 62°46′W	West R.	NS145	L&F	08	80	N/A	6.0	621.2	7.0	N/A	1,3,18,23
Pictou Causeway Pd.	45°39′N; 62°44′W	Middle R.	NS155	L&F	08	80	N/A	6.0	365.0	9.0	N/A	1,3,18,23
Piper Lake	45°21′N; 62°40′W	St. Mary's R.	ES142	L&F	07	75	25.0	6.8	5.7	3.0	1.76	1,2,4,12,21
Sutherland Lake	45°26′N; 62°23′W	East R.	NS145	L&F	07	75	33.0	6.4	50.0	9.0	4.2	1,2,9,12
West Branch Lake	45°22′N; 62°39′W	East R.	NS145	L&F	07	75	23.0	6.8	45.5	4.5	2.0	1,2,12,15
White Branch	45°23′N; 62°16′W	St. Mary's R.	ES142	L&F	07	75	N/A	6.2	4.4	2.4	1.4	2,4,12
Unnamed	45°43′N; 62°39′W	None	NS158	L&F	08	75	390.0	9.7	2.6	0.9	0.5	3,5,15
Unnamed	45°43′N; 62°39′W	Mill B.	NS160	L&F	08	75	152.0	7.5	4.5	3.6	1.9	3,5,17

Lake	Co-ordinates	Watershed Name	Watershed Code	Survey Agency	Date Mo.	Date Yr.	Conduct. (μmhos/cm)	pH	Surface Area (ha)	Depth Max.	Depth Mean	Fish Species
Unnamed	45°42′N; 62°20′W	None	NS115	L&F	07	75	157.0	7.0	9.6	1.5	1.2	2,3,5,18
Unnamed	45°23′N; 62°17′W	St. Mary's R.	ES142	L&F	06	75	22.0	6.0	2.9	2.1	1.1	4
QUEENS COUNTY												
Back Lake	44°18′N; 65°17′W	Mersey R.	SS114	CWS	07	71	21.8	4.8	78.4	5.8	2.2	1,2,3,4,5,10,12,21
Bar Pond	44°00′N; 64°43′W	McAlpine B.	SS11	DFO	09	72	N/A	6.0	6.5	9.1	2.1	1,2,4
Barnie Lake	44°22′N; 65°09′W	Mersey R.	SS114	DFO	08	72	N/A	6.5	20.2	4.6	3.1	2,3,4,21
Beaverhead Lake	44°26′N; 65°09′W	Mersey R.	SS114	L&F	08	74	42.0	6.5	15.4	6.1	1.8	1,4,5,6,12
Beaverskin Lake	44°18′N; 65°10′W	Mersey R.	SS114	CWS	06,09	71	22.0	5.6	43.3	6.8	2.8	2,3,4,5,10,12,21
Big Robertson Lake	43°53′N; 64°54′W	Robertson L.	SS125	DFO	07	72	N/A	5.5	66.3	20.0	8.0	7,18
Blueberry Pond	45°05′N; 64′35′W	None	SS109	DFO	07	72	N/A	6.5	21.5	2.4	2.1	1
Brophy Lake	44°11′N; 65°15′W	Mersey R.	SS114	L&F	08	66	N/A	N/A	17.0	2.7	2.1	4,5,21
Caduesky Lake	44°09′N; 65°13′W	Mersey R.	SS114	L&F	08	66	N/A	6.0	81.1	1.5	1.2	1,3,4,5,12,21
Cannon Lake	44°21′N; 65°08′W	Mersey R.	SS114	DFO	08	72	N/A	5.5	33.2	1.8	1.6	1,3,4,21
Coblielle Lake	44°19′N; 65°14′W	Mersey R.	SS114	CWS	06	71	22.8	5.4	131.8	6.3	2.0	1,2,3,4,5,10,12,21,26
Coblielle Lake	44°19′N; 65°14′W	Mersey R.	SS114	CWS	06,07	72	21.8	5.4	131.8	6.3	2.0	1,2,3,4,5,10,12,21,26
Dunn Lake	44°16′N; 65°17′W	Mersey R.	SS114	L&F	07	64	N/A	6.4	34.3	5.3	3.2	2,3,4,5,21
Eighth Lake	44°08′N; 65°14′W	Mersey R.	SS114	L&F	06	66	N/A	5.5	30.0	8.8	N/A	1,2,3,4,5,10,12,21
First Beaver Lake	44°13′N; 65°20′W	Mersey R.	SS114	L&F	07,08	66	N/A	5.0	20.0	1.8	1.5	2,5,15
First Ring Lake	44°15′N; 65°15′W	Mersey R.	SS114	L&F	07	64	N/A	6.4	7.2	4.6	2.7	4,5,21
Freeman Lake	44°26′N; 65°07′W	Medway R.	SS106	DFO	08	72	N/A	6.5	15.2	3.7	2.1	Not fished
George Lake	44°20′N; 65°13′W	Mersey R.	SS114	CWS	08	72	25.7	5.0	77.8	8.5	2.4	1,3,4,10,12,21
Grafton Lake	44°23′N; 65°11′W	Mersey R.	SS114	CWS	07	71	25.6	5.7	270.0	10.0	2.8	1,2,3,4,5,10,12,21
Great Pine Lake	44°13′N; 65°23′W	Roseway R.	FA6	L&F	07	74	35.0	5.0	50.0	3.7	1.1	4
Harlow Lake	44°17′N; 65°17′W	Mersey R.	SS114	L&F	05	74	27.0	4.5	2.9	5.5	3.3	4,12
Harmony Lake	44°24′N; 65°06′W	Medway R.	SS106	DFO	08	72	N/A	6.5	354.1	10.7	4.6	1,3,21
Herring Cove Lake	44°08′N; 65°43′W	Herring Cove B.	SS113	DFO	07	72	N/A	6.0	381.2	6.7	4.6	1,4,10
High Lake	44°21′N; 65°16′W	Mersey R.	SS114	CWS	08	71	23.2	4.9	3.	2.8	1.5	1,2,4,5,10,12,21
High Lake	44°21′N; 65°16′W	Mersey R.	SS114	CWS	07	72	23.9	5.2	3.8	2.8	1.5	1,2,3,4,5,10,12,21
Hilchemakaar Lake	44°17′N; 65°14′W	Mersey R.	SS114	CWS	07	71	26.3	5.7	95.4	7.3	2.0	1,2,3,4,5,10,12,21
Hilchemakaar Lake	44°17′N; 65°14′W	Mersey R.	SS114	CWS	06	72	24.6	5.7	95.4	7.3	2.0	1,2,3,4,5,10,12,21
Hunt Lake	44°23′N; 65°00′W	Mersey R.	SS114	DFO	08	72	N/A	6.5	3.3	7.0	4.6	1,3,21
Irving Lake	44°17′N; 65°20′W	Mersey R.	SS114	L&F	06	74	32.0	4.6	135.9	7.9	2.4	4
Jordan Lake	44°05′N; 65°14′W	Jordan R.	SS153	L&F	08	74	28.0	6.1	1267.7	3.1	1.3	1,3,4,21

		Watershed		Survey	Date		Conduct.		Surface	Depth		
Lake	Co-ordinates	Name	Code	Agency	Mo.	Yr.	(μmhos/cm)	pH	Area (ha)	Max.	Mean	Fish Species
Kejimkujik Lake	44°23′N; 65°15′W	Mersey R.	SS114	CWS	05,06 08	71	23.8	5.0	2435.0	19.2	4.4	1,2,3,4,5,7,10,12 15,20,21,26
Kejimkujik Lake	44°23′N; 65°15′W	Mersey R.	SS114	CWS	05,08	72	25.8	5.2	2435.0	19.2	4.4	1,2,3,4,5,20,21,26
Little Kempton Lake	44°22′N; 65°11′W	Mersey R.	SS114	CWS	08	72	24.0	5.4	2.5	2.5	1.4	2,4,21
Little Peskowesk Lake	44°17′N; 65°13′W	Mersey R.	SS114	CWS	06	71	25.2	5.1	11.3	4.0	1.4	1,2,3,4,5,10,12,21
Little Peskowesk Lake	44°17′N; 65°13′W	Mersey R.	SS114	CWS	06	72	24.7	5.4	11.3	4.0	1.4	1,2,3,4,5,10,12,21
Little Robertson L.	43°53′N; 64°54′W	Robertson L.	SS125	DFO	06	72	N/A	5.0	9.3	8.4	4.0	7
Little Silver Lake	44°11′N; 65°17′W	Mersey R.	SS114	L&F	08	66	N/A	5.5	20.6	2.4	1.8	4,5,12,21
Little Tupper Lake	44°14′N; 65°16′W	Mersey R.	SS114	L&F	08	74	24.0	6.5	99.6	12.8	3.6	1,2,3
Loon Lake	44°19′N; 65°11′W	Mersey R.	SS114	CWS	08	72	25.7	5.5	73.8	8.5	2.0	1,3,4,5,10,12,21
Louis Lake	43°54′N; 64°56′W	Douglas B.	SS126	DFO	08	72	N/A	5.0	26.3	4.0	1.6	Not fished
Lower Porcupine L.	44°08′N; 65°15′W	Jordan R.	SS153	L&F	08	64	N/A	6.5	54.2	4.9	2.7	1,3,4,5,12,21
Lower Silver Lake	44°17′N; 65°16′W	Mersey R.	SS114	CWS	07	71	23.1	5.6	24.7	5.3	1.8	1,2,3,4,5,10,12,21
Lower Silver Lake	44°17′N; 65°16′W	Mersey R.	SS114	CWS	07	72	21.3	5.4	24.7	5.3	1.8	1,2,3,4,5,10,12,21
McGinty Lake	44°22′N; 65°10′W	Mersey R.	SS114	CWS	07	71	25.8	5.6	4.4	4.0	1.4	1,2,3,4,5,10,12
McGinty Lake	44°22′N; 65°10′W	Mersey R.	SS114	CWS	06	72	25.6	6.4	4.4	4.0	1.4	1,2,3,4,5,10,12
McGowan Lake	44°26′N; 65°03′W	Medway R.	SS106	L&F	09	74	28.0	6.0	430.4	12.8	2.8	5,12
Menchan Lake	44°20′N; 65°07′W	Mersey R.	SS114	DFO	08	72	N/A	6.5	52.7	15.6	6.0	1,2,3
Menchan Lake	44°16′N; 65°13′W	Mersey R.	SS114	L&F	05	74	26.0	6.3	2.6	3.1	1.8	Not fished
Minard Lake	44°25′N; 65°10′W	Mersey R.	SS114	L&F	08	74	37.0	6.3	111.9	5.8	2.4	2,4,5,12,21,26
Morton Lake	44°17′N; 65°17′W	Mersey R.	SS114	L&F	05	74	27.0	6.5	3.2	5.5	3.0	4
Mountain Lake	44°19′N; 65°16′W	Mersey R.	SS114	CWS	07,08	71	22.4	5.1	136.4	14.3	4.3	1,2,3,4,10,21,26
Mountain Lake	44°19′N; 65°16′W	Mersey R.	SS114	CWS	06,09	72	22.4	5.1	136.4	14.3	4.3	1,2,3,4,10,21,26
Mud Lake	44°17′N; 65°13′W	Mersey R.	SS114	CWS	06	72	26.0	5.4	7.0	2.2	1.0	1,2,4,10,21
North Cranberry L.	44°20′N; 65°14′W	Mersey R.	SS114	CWS	05,08	71	19.5	5.1	34.3	5.0	1.5	2,4,5,10,12,21
North Cranberry L.	44°20′N; 65°14′W	Mersey R.	SS114	CWS	06	72	21.2	4.9	34.3	5.0	1.5	2,4,5,10,12,21
Path Lake	43°52′N; 64°56′W	London B.	SS127	DFO	07	72	N/A	6.2	21.9	16.0	4.0	3
Peskowesk Lake	44°19′N; 65°17′W	Mersey R.	SS114	CWS	06,07	71	26.0	4.7	685.0	13.0	3.9	1,2,3,4,5,10,15,21
Peskowesk Lake	44°19′N; 65°17′W	Mersey R.	SS114	CWS	06,08	72	27.0	5.2	685.0	13.0	3.9	1,2,3,4,5,15,21,26
Puzzle Lake	44°19′N; 65°14′W	Mersey R.	SS114	CWS	05,08	71	20.8	4.4	33.7	6.1	2.7	2,3,4,12,21
Puzzle Lake	44°19′N; 65°14′W	Mersey R.	SS114	CWS	06,08	72	21.3	4.8	33.7	6.1	2.7	2,3,4,12,21
Sand Lake	44°15′N; 65°15′W	Mersey R.	SS114	L&F	05	74	30.0	4.6	116.9	9.1	2.8	1,2,4,12,21
Scott Lake	44°22′N; 65°05′W	Medway R.	SS106	L&F	08	74	47.0	6.5	20.6	2.1	N/A	1,4,5,12,21

Lake	Co-ordinates	Watershed Name	Watershed Code	Survey Agency	Date Mo.	Date Yr.	Conduct. (μmhos/cm)	pH	Surface Area (ha)	Depth Max.	Depth Mean	Fish Species
Scott Lake	44°22′N; 65°05′W	Medway R.	SS106	L&F	09	64	N/A	6.6	25.8	3.0	2.4	1,2,3,5,12,21
Second Beaver Lake	44°13′N; 65°19′W	Mersey R.	SS114	L&F	07	66	N/A	4.0	17.0	1.8	1.5	4,5
Second Ring Lake	44°15′N; 65°15′W	Mersey R.	SS114	L&F	07	64	N/A	5.7	8.4	4.9	3.1	1,2,3,4,5,12,21
Silver Lake	44°07′N; 65°13′W	Mersey R.	SS114	L&F	08	64	N/A	6.6	103.7	3.1	2.0	1,2,3,4,5,12,21
Siskech Lake	44°15′N; 65°21′W	Mersey R.	SS114	L&F	06	74	30.0	4.7	144.5	11.6	3.0	4
Snake Lake	44°21′N; 65°12′W	Mersey R.	SS114	CWS	07	72	25.9	5.0	12.7	2.5	1.4	1,3,4,5,10,12,21
Tobeatic Lake	44°12′N; 65°17′W	Mersey R.	SS114	L&F	08	74	26.0	6.0	530.4	10.1	3.3	1,5,21
Tupper Lake	44°27′N; 65°00′W	Medway R.	SS106	L&F	08	74	24.0	6.0	439.9	13.7	2.9	18
Turtle Lake	44°22′N; 65°08′W	Mersey R.	SS114	L&F	08	74	30.0	6.7	77.9	9.1	3.1	1,3,4,12,21
Upper Silver Lake	44°17′N; 65°15′W	Mersey R.	SS114	CWS	07	71	22.0	5.5	24.3	5.8	2.3	1,2,3,4,10,12,21
Upper Silver Lake	44°17′N; 65°15′W	Mersey R.	SS114	CWS	07	72	22.3	5.9	24.3	5.8	2.3	1,2,3,4,10,12,21
Victoria Lake	44°00′N; 64°41′W	Victoria L.	SS115	DFO	06	72	N/A	6.1	28.4	10.0	4.0	2,7
RICHMOND COUNTY												
Barren Lake	45°42′N; 60°35′W	Grand R.	CBE170	L&F	08	74	N/A	N/A	62.5	4.5	2.3	2,15
Condons Lake	45°38′N; 60°47′W	Condon B.	CBE145	L&F	08	77	44.0	6.5	31.0	15.0	4.2	1,3,5,12
Cook Lake	45°42′N; 60°54′W	River Tillard	CBC285	L&F	07	74	38.0	6.0	79.7	12.2	2.9	1,2,5,12,15
Cranberry Lake	45°41′N; 60°53′W	River Tillard	CBC285	L&F	07	74	47.0	6.3	13.2	6.1	2.6	2,3
Crooked Lake	45°42′N; 60°21′W	Framboise R.	CBC153	L&F	08	74	N/A	6.5	11.2	4.6	1.2	2,3,5,6,16,18
Ferguson Lake	45°39′N; 60°36′W	L'Archeveque C.	CBE168	L&F	07	74	N/A	6.5	51.1	10.7	4.3	3,5,15
Gillis Lake	45°40′N; 60°47′W	Grand R.	CBE170	L&F	08	80	83.0	6.0	6.1	1.6	0.8	Not fished
Lake Uist	45°48′N; 60°34′W	Grand R.	CBE170	L&F	08	80	48.0	7.0	280.8	N/A	N/A	2,5,9,17
Loch Lomond Lake	45°45′N; 60°36′W	Grand R.	CBE170	L&F	08	74	N/A	6.8	671.3	17.7	6.9	2,6,17
Long Lake	45°41′N; 60°55′W	River Tillard	CBC285	L&F	08	74	N/A	6.5	71.1	15.9	6.6	2,3,5,7,12
MacKay Lake	45°43′N; 60°50′W	George C.	CBC281	L&F	07	74	100.0	6.2	42.9	18.3	5.2	3,5,18
Unnamed Lake	45°42′N; 60°23′W	Marie Joseph B.	CBE155	L&F	08	74	N/A	6.5	21.4	9.1	4.1	5,12,16
Upper Marie Joseph L.	45°51′N; 60°25′W	Marie Joseph B.	CBE155	L&F	08	77	44.0	7.0	44.5	7.3	1.6	2
SHELBURNE COUNTY												
Alvin Harbour	43°43′N; 65°24′W	Alvin L.	FA10	L&F	06	80	43.5	6.5	21.3	4.0	1.7	4,5
Beaverdam Lake	43°54′N; 65°23′W	Roseway R.	FA6	L&F	08	80	31.5	6.3	15.0	3.3	1.6	4,12,21
Beaverdam Lake	43°40′N; 65°26′W	Round Bay R.	FA15	L&F	06	80	39.0	6.0	136.4	6.0	2.0	2,4
Birchtown Lake	43°51′N; 65°24′W	Birchtown B.	FA7	L&F	08	80	33.0	6.0	253.7	2.0	0.5	2,4,12,21

Lake	Co-ordinates	Watershed Name	Watershed Code	Survey Agency	Date Mo.	Date Yr.	Conduct. (μmhos/cm)	pH	Surface Area (ha)	Depth Max.	Depth Mean	Fish Species
Black Duck Lake	44°07′N; 65°16′W	Jordan R.SS153	L&F	04	80	45.0	5.5	46.1	1.0	0.1	1,4,12,21	
Churchover L. (North)	43°42′N; 65°23′W	Churchover L.	FA11	L&F	08	80	41.0	6.0	98.1	12.0	3.1	4
Clamshell Lake	44°02′N; 65°29′W	Roseway R.	FA6	L&F	08	67	N/A	5.0	71.2	2.4	1.7	2,3,4,10
Courtney Lake	43°49′N; 65°23′W	Roseway R.	FA6	L&F	07	80	30.0	5.3	124.6	2.0	0.6	2,4,12,21
Deception Lake	43°54′N; 65°23′W	Roseway R.	FA6	L&F	07	80	26.0	6.0	265.1	7.0	12.9	4,12,21
Dexter Lake	43°39′N; 65°21′W	Dexter L.	FA14	L&F	06	80	43.0	6.3	87.0	3.0	2.2	4
Lake George	44°00′N; 66°03′W	Purney B.	SS154	L&F	07	80	40.0	6.4	113.9	3.0	1.7	4,12,18,21
Green Harbour Lake	43°49′N; 65°08′W	East B.	SS150	L&F	07	80	32.5	6.1	149.0	2.0	1.4	1,4
Handsled Lake	44°12′N; 65°22′W	Roseway R.	FA6	L&F	06	74	28.0	5.0	47.8	10.7	3.7	4
Harlow Lake	44°07′N; 65°17′W	Jordan R.	SS153	L&F	07	66	N/A	5.0	11.7	4.6	3.0	1,2,3,5,12,21
Harper Lake	43°48′N; 65°28′W	Clyde R.	FA18	L&F	07	80	31.0	6.0	221.0	2.0	1.3	2,4,12,21
John Lake	44°00′N; 65°25′W	Roseway R.	FA6	L&F	08	80	26.0	6.0	149.1	3.2	1.3	1,4,12,21
Jones Lake	43°57′N; 65°26′W	Roseway R.	FA6	L&F	07	80	27.5	6.0	83.8	2.0	1.2	4,21
Junction Lake	44°14′N; 65°23′W	Roseway R.	FA6	L&F	07	74	32.0	4.5	95.0	9.8	2.3	4
Little Tobeatic Lake	44°10′N; 65°20′W	Mersey R.	SS114	L&F	07	74	29.0	5.6	119.9	9.8	3.1	1,3,4,21
Long Lake	44°09′N; 65°24′W	Jordan R.	SS153	L&F	07	74	32.0	5.5	10.2	5.5	1.9	2,4,21
Longview Lake	44°05′N; 65°19′W	Jordan R.	SS153	L&F	06	66	N/A	5.0	93.2	3.1	N/A	2,3,4,5,21,12
McKay Lake (West)	43°55′N; 65°24′W	Roseway R.	FA6	L&F	08	80	26.5	5.8	68.3	5.1	1.7	1,4,10,21
McKay Lake (East)	43°55′N; 65°24′W	Roseway R.	FA6	L&F	08	80	26.5	6.0	28.0	9.0	2.2	3,21
Mink Lake	44°09′N; 65°26′W	Roseway R.	FA6	L&F	06	74	27.0	4.4	221.0	13.1	2.9	4
Mullins Lake	44°07′N; 65°17′W	Jordan R.	SS153	L&F	07	66	N/A	5.0	18.4	7.0	3.1	1,2,4,5,12,15,
Newmoon Lake	44°12′N; 65°23′W	Roseway R.	FA6	L&F	07	74	33.0	4.0	39.5	4.6	1.3	4
Odgen Lake	43°47′N; 65°13′W	Jordan B.	SS153	L&F	07	80	32.5	6.0	17.7	4.8	1.3	2,4,21
Philip Lake	43°58′N; 65°25′W	Roseway R.	FA6	L&F	07	80	27.0	6.0	107.0	2.9	1.2	4,5,12,21
Roseway Lake	44°10′N; 65°24′W	Roseway R.	FA6	L&F	06	74	28.0	4.5	241.3	12.2	3.6	4
Silvery Lake	44°08′N; 65°24′W	Jordan R.	SS153	L&F	08	75	N/A	N/A	80.2	4.9	N/A	2,5,10,12,21
Skudiak Lake	44°08′N; 65°25′W	Roseway R.	FA6	L&F	06	74	28.0	4.6	96.0	31.1	8.2	4,5
Spectacle Lake	44°08′N; 65°22′W	Jordan R.	SS153	L&F	06	74	30.0	5.0	87.3	1.8	0.8	1,4,21
Unnamed Lake	43°48′N; 65°07′W	East B.	SS150	L&F	07	80	42.0	5.0	11.9	1.6	1.0	5,12
Unnamed Lake	44°11′N; 65°20′W	Mersey R.	SS114	L&F	06	74	29.0	4.8	6.8	4.6	1.4	4,21
Unnamed Lake	44°10′N; 65°20′W	Mersey R.	SS114	L&F	07	74	29.0	5.2	9.0	6.7	2.5	2,12,21
Wainwright Lake	44°09′N; 65°23′W	Jordan R.	SS153	L&F	06	74	29.0	6.5	20.2	15.5	3.9	2,3,4,12,21
Wall Lake	43°46′N; 65°04′W	Wall B.	SS145	L&F	07	80	41.0	5.0	52.9	1.6	1.3	4,12
West Horseshoe Lake	44°02′N; 65°29′W	Roseway R.	FA6	L&F	08	67	N/A	5.0	90.3	9.5	3.3	2,4,5,21

Lake	Co-ordinates	Watershed Name	Watershed Code	Survey Agency	Date Mo.	Date Yr.	Conduct. (μmhos/cm)	pH	Surface Area (ha)	Depth Max.	Depth Mean	Fish Species
VICTORIA COUNTY												
Baddeck Lake	46°17′N; 60°44′W	Baddeck R.	CBC150	L&F	08	78	N/A	6.5	103.2	6.0	1.5	2,23
Baldwin Lake	46°45′N; 60°37′W	Middle Aspy R.	CBC23	CWS	07	76	30.0	5.8	44.4	3.0	1.2	Fished-No Success
Branch Pond	46°44′N; 60°27′W	Black B.	CBC36	CWS	07	76	32.0	5.2	14.9	6.5	2.4	2
Canns Lake	46°40′N; 60°26′W	Cann's B.	CBC42	CWS	06	76	26.0	6.2	10.4	9.2	2.0	2
Dalem Lake	46°15′N; 60°25′W	Aconi B.	CBE37	L&F	07	72	N/A	6.6	26.3	9.8	4.7	1,2
Dundas L. No. 4	46°42′N; 60°32′W	Dundas B.	CBC41	CWS	07	76	30.0	5.7	16.3	2.5	1.5	10
Freshwater Lake	46°38′N; 60°24′W	Freshwater L.	CBC45	CWS	06,10	76	155.0	7.1	42.2	16.0	6.5	2,3,5,10,15,17,18
Glasgow Lake	46°49′N; 60°30′W	Glasgow B.	CBC24	CWS	10	76	23.0	5.5	23.9	14.6	4.5	10
Gwinn Lake	46°47′N; 60°33′W	Middle Aspy R.	CBC23	CWS	08	76	26.0	5.7	23.0	3.3	1.1	2
Jigging Cove Lake	46°47′N; 60°20′W	None	CBC34	CWS	06	76	79.0	5.1	6.2	2.0	0.9	2
John Dee Lake	46°49′N; 60°31′W	Middle Aspy R.	CBC23	CWS	10	76	27.0	6.2	23.5	9.4	2.1	2
Lobster Lake	46°48′N; 60°31′W	Halfway B.	CBC33	CWS	10	76	26.0	5.1	9.5	1.9	1.0	2
Long Lake	46°49′N; 60°29′W	Halfway B.	CBC33	CWS	10	76	29.0	5.2	6.6	1.5	0.6	2
Lower Redhead Pond	46°06′N; 60°42′W	Lower Redhead P.	CBC133	L&F	08	78	2000.0	9.0	3.0	3.5	0.8	2,3,17,18,23,24,30
MacDougalls Lake	46°40′N; 60°26′W	None	CBC43	CWS	06	76	31.0	6.2	5.0	11.5	3.4	2
Paquette Lake	46°50′N; 60°26′W	Effie's B.	CBC25	CWS	07	76	63.0	7.2	5.0	1.9	0.9	10
Patterson Lake	46°14′N; 60°27′W	Aconi B.	CBE37	L&F	04	81	34.0	6.5	7.1	1.5	0.4	2,12
Round Lake	46°48′N; 60°30′W	Halfway B.	CBC33	CWS	09	76	29.0	5.5	14.4	2.0	1.0	2
Roundhill Lake No.1	46°47′N; 60°34′W	Middle Aspy R.	CBC23	CWS	08	76	30.0	6.1	17.1	4.4	1.4	2
Roundhill Lake No.2	46°47′N; 60°33′W	Middle Aspy R.	CBC23	CWS	08	76	30.0	6.0	5.1	2.0	0.9	2
Snake Cat Lake	46°17′N; 60°43′W	Baddeck P.	CBC150	L&F	08	78	31.0	6.5	22.3	3.0	1.1	2
Timber Lake	46°22′N; 60°40′W	North R.	CBC86	L&F	06	76	N/A	6.6	34.0	12.0	4.9	2,5
Two Island Lake	46°39′N; 60°35′W	Clyburn B.	CBC44	CWS	08	76	18.0	6.2	25.6	5.5	1.4	2
Unnamed Lake	46°22′N; 60°42′W	North R.	CBC86	L&F	08	78	43.0	6.0	7.7	20.0	7.8	Fished-No Success
Upper Redhead Pond	46°07′N; 60°41′W	Upper Redhead P.	CBC132	L&F	08	78	20000.0	9.0	3.2	6.0	2.1	3,8,17,18,23,24,30
Warren Lake	46°43′N; 60°24′W	Warren B.	CBC38	CWS	06,10	76	33.0	5.8	89.8	31.0	15.9	2,3,10,18
Warren Lake	46°43′N; 60°24′W	Warren B.	CBC38	CWS	10	74	33.0	5.8	89.8	31.0	15.9	2,3,10,18
YARMOUTH COUNTY												
Agard Lake	43°55′N; 66°00′W	Tusket R.	FA53	L&F	07	81	41.6	6.3	45.8	8.0	3.0	1,3,4,5,12,18,21
Allen Lake	43°57′N; 66′09′W	None	FA66	DFO	07	74	87.9	6.8	95.8	12.0	3.2	1,2,3,4,10,12,18,21
Allen Lake	43°57′N; 66°09′W	Little L.	FA66	L&F	08	81	114.0	7.3	90.5	14.0	3.5	1,3,4,21

		Watershed			Date					Depth		
Lake	Co-ordinates	Name	Code	Survey Agency	Mo.	Yr.	Conduct. (µmhos/cm)	pH	Surface Area (ha)	Max.	Mean	Fish Species
Annis Lake	44°03′N; 60°01′W	Tusket R.	FA53	L&F	06,07	81	55.0	6.3	177.6	9.8	3.2	1,2,3,4,12,21
Back Lake	43°54′N; 65°52′W	Tusket R.	FA53	L&F	09	79	440.0	5.7	20.2	4.0	2.0	1,4,21
Beaver Creek Lake	44°05′N; 65°31′W	Roseway R.	FA6	L&F	07	74	40.0	4.0	15.1	3.1	2.3	4
Bird Lake	43°58′N; 65°57′W	Tusket R.	FA53	DFO	08	74	41.1	6.4	19.0	6.0	3.1	3,10,21
Bower Lake	44°05′N; 65°46′W	Tusket R.	FA53	L&F	08	68	N/A	N/A	12.9	4.3	2.1	2,3,4,9,21
Brazil Lake	44°00′N; 66°00′W	Tusket R.	FA53	L&F	07	81	59.0	6.5	99.7	10.6	3.4	1,3,4,12,20,21
Brenton Lake	43°58′N; 66°04′W	Milton L.	FA62	DFO	06	74	47.9	6.5	54.4	3.0	1.4	1,3,4,21
Brenton Lake	43°58′N; 66°04′W	Milton L.	FA62	L&F	08	81	62.0	5.6	49.1	3.6	1.5	1,3,4,5,21
Bunker Lake	43°55′N; 66°05′W	Milton L.	FA62	DFO	06	74	51.1	6.7	41.5	3.0	1.4	1,3,4,10,21,27
Canoe Lake	43°57′N; 65°46′W	Tusket R.	FA53	L&F	09	79	490.0	6.0	111.2	9.0	1.9	1,4,10,18,21
Chandler Lake	43°51′N; 66°04′W	Chebogue R.	FA58	DFO	06	74	82.1	5.4	21.0	1.5	1.0	2,4
Chegoggin Lake	43°55′N; 66°08′W	Chegoggin R.	FA64	DFO	07	74	N/A	6.0	112.0	6.0	2.3	2,3,18,21
Chegoggin Lake	43°55′N; 66°08′W	Chegoggin R.	FA64	L&F	08	81	77.0	6.3	101.2	8.0	2.6	2,3,12,21
Churchill Lake	43°59′N; 66°08′W	Beaver R.	FA67	DFO	07	74	78.0	6.7	40.9	6.0	2.3	1,2,3,4,12,21
Churchill Lake	43°59′N; 66°08′W	Beaver R.	FA67	L&F	08	81	105.0	7.5	39.0	8.0	2.8	1,3,4,12,21
Clearwater Lake	43°53′N; 65°55′W	Eel L.	FA49	L&F	08	68	N/A	N/A	118.9	22.6	6.2	1,3,22
Coggins Lake	43°59′N; 66°07′W	Beaver R.	FA67	DFO	07	74	65.2	6.4	40.0	2.0	1.4	1,2,3,4,18,21
Crain Lake	44°08′N; 65°28′W	Roseway R.	FA6	L&F	05	74	30.0	4.7	26.8	12.2	N/A	4
Darlings Lake	43°58′N; 66°08′W	Beaver R.	FA67	DFO	07	74	76.9	7.0	140.8	4.0	1.8	1,2,3,12,18,21
Darlings Lake	43°58′N; 66°08′W	Beaver R.	FA67	L&F	08	81	96.0	7.0	121.2	8.0	1.7	1,3,5,12,21,23
Demoliter Lake	44°08′N; 65°29′W	Roseway R.	FA6	L&F	05	74	28.0	N/A	10.4	8.6	N/A	4
Doctors Lake	43°53′N; 66°06′W	Milton L.	FA62	DFO	06	74	66.4	6.2	130.2	8.0	2.9	3,18,21,22
Doctors Lake	43°53′N; 66°06′W	Milton L.	FA62	L&F	08	81	91.0	6.5	113.3	9.3	3.3	1,3,22
Duck Lake	43°51′N; 65°55′W	Eel L.	FA49	L&F	09	79	1010.0	6.5	45.7	7.0	2.2	3,18,22
Eel Lake	43°50′N; 65°55′W	Eel L.	FA49	L&F	07	79	12900.0	7.9	310.3	6.0	2.5	3,18,23,24,25
First Bear Lake	44°07′N; 65°40′W	Tusket R.	FA53	L&F	06	74	48.0	4.6	23.3	7.9	2.4	4
Frost Lake	43°48′N; 65°51′W	None	FA43	L&F	07	79	47.0	6.8	26.1	9.0	3.3	3,4,21
Great Pubnico Lake	43°42′N; 65°43′W	Barrington R.	FA27	L&F	08	79	34.0	6.0	1810.9	6.0	1.5	2,4,21
Harris Lake	43°54′N; 66°00′W	Tusket R.	FA53	L&F	06	81	50.0	5.9	42.8	8.0	2.1	1,3,4,9,12,18,21,22
James Lake	43°56′N; 65°46′W	Tusket R.	FA53	L&F	07	79	N/A	6.5	8.5	9.0	3.8	3,4,12,21
Jesse Lake	44°02′N; 66°00′W	Tusket R.	FA53	DFO	08	74	41.8	6.4	27.9	6.0	2.4	1,2,3,4,7,21
Jesse Lake	44°02′N; 66°00′W	Tusket R.	FA53	L&F	06	81	51.0	6.3	23.8	5.0	2.5	2,3,4,12,21
Killam Lake	44°00′N; 66°05′W	Beaver R.	FA67	DFO	07	74	50.6	6.4	133.0	8.0	2.3	1,2,3,4,18,21

Lake	Co-ordinates	Watershed		Survey Agency	Date		Conduct. (µmhos/cm)	pH	Surface Area (ha)	Depth		Fish Species
		Name	Code		Mo.	Yr.				Max.	Mean	
Killam Lake	44°00′N; 66°05′W	Beaver R.	FA67	L&F	07	81	54.0	6.5	123.4	8.4	2.6	1,3,4,12,21
Laca Pic Lake	43°50′N; 65°55′W	Argyle R.	FA44	L&F	08	79	36.0	6.5	157.4	4.0	2.4	1,2,3,4,21
Little Brazil Lake	44°00′N; 66°01′W	Tusket R.	FA53	L&F	07	81	58.0	5.8	18.5	2.6	1.2	1,3,21
Little Skinner Lake	44°00′N; 65°52′W	Tusket R.	FA53	L&F	08	68	N/A	N/A	10.1	11.3	6.1	1,2,21
Louis Lake	43°56′N; 65°45′W	Tusket R.	FA53	L&F	08	68	N/A	N/A	60.4	5.2	3.0	2,3
Marcel Lake	43°53′N; 65°54′W	Eel L.	FA49	L&F	07	79	390.0	6.5	31.5	14.0	2.7	3,4,18,22
McGill Lake	44°07′N; 65°29′W	Roseway R.	FA6	L&F	05	74	29.0	4.3	95.2	16.7	N/A	4
Milton Lake	43°52′N; 66°07′W	Milton L.	FA62	DFO	06	74	69.6	6.3	78.7	9.0	2.9	1,3,4,18,22
Mingo Beck Lake	43°52′N; 65°54′W	Eel L.	FA49	L&F	07	79	43.0	6.3	65.1	2.0	1.3	3,22
Moses Lake	43°52′N; 65°51′W	Argyle R.	FA44	L&F	07	79	38.0	6.4	78.9	13.0	4.8	1,3,4,21
Robbins Lake	43°55′N; 66°08′W	Chegoggin R.	FA64	L&F	08	81	75.0	6.3	11.4	6.0	2.2	3,5,21
Salmon Lake	43°52′N; 66°01′W	Tusket R.	FA53	L&F	06	81	49.9	6.0	156.8	6.8	2.0	1,2,3,4,12,21,22
Somes Lake	43°58′N; 65°54′W	Tusket R.	FA53	L&F	08	68	N/A	N/A	88.2	10.7	5.0	1,3,4,12
South Corning Lake	44°01′N; 66°06′W	Beaver R.	FA67	L&F	08,09	81	66.0	6.5	55.6	2.3	1.2	2,3,4,12,21
South Wallace Lake	44°08′N; 65°41′W	Tusket R.	FA53	L&F	06	74	39.0	4.3	82.2	8.2	2.6	Fished-No Success
Three Island Lake	44°02′N; 66°04′W	Salmon R.	FA69	L&F	08,09	81	55.0	6.3	57.4	4.0	1.2	1,3,4,5,10,12,21
Trefry Lake	43°50′N; 66°03′W	Chebogue R.	FA58	DFO	06	74	55.0	7.0	30.0	14.0	2.9	2,4,18
Trefry Lake	43°50′N; 66°03′W	Chebogue R.	FA58	L&F	09	81	71.0	7.0	27.1	14.2	3.0	4,5,18
Unnamed (Bass Lake)	44°03′N; 66°02′W	Salmon R.	FA69	L&F	08	68	N/A	N/A	32.8	9.8	4.6	2,3
Utley Lake	43°54′N; 66°09′W	Utley L.	FA65	L&F	08	81	120.0	6.8	43.8	6.0	2.8	3,22
Vaughan Lake	43°55′N; 65°58′W	Tusket R.	FA53	L&F	08	79	34.0	6.8	467.4	18.0	5.1	1,3,4,12,21
Wellington Lake	43°57′N; 66°05′W	Chegoggin R.	FA64	L&F	08	81	65.0	5.1	132.3	12.0	4.0	2,5
West Clearwater Lake	43°52′N; 65°53′W	Argyle R.	FA44	L&F	08	79	42.0	6.7	108.4	8.0	3.1	1,3,4,18,21
Whetstone Lake	44°06′N; 65°29′W	Roseway R.	FA6	L&F	05	74	33.0	4.7	58.3	6.1	1.6	4,21

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AN INITIAL INVESTIGATION OF LIPIDS AND FATTY ACIDS OF NOVA SCOTIAN "SOFT" COD

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"Soft" cod *Gadus morhua* are a regular economic problem in fisheries on the Scotian Shelf. A preliminary study has been conducted and a low fat content in viscera is the principal abnormality. The lipid content, lipid class profiles, and fatty acids of the fillets from two "soft oily" cod were also examined in this study and were relatively similar to those of one "control" fish as well as to "normal" Atlantic cod. It was however observed that the fatty acid details of the soft oily cod were slightly different from those in the literature for "normal" Atlantic cod. The aquarium-held control fish supplied by Fisheries and Oceans Canada also had a slightly different fatty acid composition. Lipids could not be directly associated with the soft cod condition.

La présence de cabillaud "mou" est un problème économique fréquent dans les pêcheries de la plate-forme "Scotian". Une étude préliminaire a montré que l'abnormalité principale est le teneur en lipides bas des viscères. Le teneur en lipides, le profile de classe de lipides, et des acides gras des filets de deux capabillauds "moux et gras" etaient examiné dans cette étude et on été relativement similaires a ceux d'un poisson de contrôle aussi bien qu'a ceux d'un cabillaud d'Atlantique "normale". Cependant, on a remarqué que les détails des acides gras de ces cabillauds étaient légèrement différentes de celles trouvées dans la littérature pour le cabillaud d'Atlantique "normale". La composition des acides gras du poisson fourni par la Département de Pêches et d'Océans du Canada et maintenu en aquarium était aussi légèrement différente. La condition des cabillauds "moux et gras" ne pouvait pas etre liés directement aux lipides.

Introduction

"Soft" cod is a seasonal and localized problem in the Nova Scotian fishing industry but of unknown etiology. In mid to late summer, and usually in specific areas, for example the Emerald Bank, cod *Gadus morhua* can be taken but are difficult to handle and/or process because of the "soft" musculature. This condition is sometimes apparent when the fish are caught, but it may also develop after a few days on ice, and can occur in haddock and other species. Fishermen avoid known soft cod areas and often have to go further afield to catch cod. It is therefore an economic problem of some significance.

Previous investigations by Fisheries and Oceans Canada showed that no known disease, protozoan, or bacterial infection could be associated with the soft cod problem. The observation that such fish were feeding heavily, often on sand launce

Ammodytes americanus, suggested a dietary factor. In an examination of sand launce oil (Ackman and Eaton 1971) a non-saponifable content of 2.4% was noted, but the material was not defined. This was higher by a factor of 2 to 4 than for herring oils, and agreed with a report of 3.56% of unsaponifiable material in North Sea sand launce (Holmer 1967). This suggested an investigation of lipids as a starting point for the soft cod problem.

Occasional reports of soft cod or haddock having a dimethyl sulfide odor (cf. Ackman et al. 1967) also suggested a dietary factor, but not necessarily lipid-oriented.

Materials and Methods

Fish samples

Fillets, stomachs and all other viscera from seven cod samples were supplied to the Canadian Institute of Fisheries Technology on 25th October, 1984 by Fisheries and Oceans Canada, for analyses for lipid content and lipid class and fatty acid profiles. Out of these seven fish, four were categorized by Fisheries and Oceans Canada as "soft oily" cod. The other three were control fish, from stocks maintained in the Fisheries and Oceans aquarium in Halifax. Fish described as dressed had been gutted prior to receipt and viscera were not available. The code names and the description of the samples are given in Table I.

Analyses

The lipids were extracted with chloroform: methyl alcohol: water according to the Bligh and Dyer (1959) procedure. The recovered lipids were analysed for lipid class composition by the Iatroscan (Technical Marketing Ass.) technique (Ackman 1981). Chromarods-S were developed in hexane: diethyl ether: formic acid 97:3:1 (v/v/v). Some selected total lipid samples were transesterified with boron trifluoride: methyl alcohol (Morrison and Smith 1964). The recovered fatty acid methyl esters were examined by Gas-liquid chromatography (*GLC*) on a Supelcowax-10 (Supelco Canada Ltd.) fused silica capillary column, 50 m x 0.24 mm, as described by Ackman (1986).

Table I Description of the samples and their lipid percentages

	% Lipid (w/w)		
Sample*	Fillet	Viscera**	Stomach and Contents
Dressed SO-1	0.77	—	—
Round SO-2	0.71	13.4	0.98
Dressed SO-3	0.61	—	—
Round SO-4	0.63	16.2	2.04
Round CO-1	0.68	55.3	4.82
Round CO-2	0.64	36.6	1.85
Dressed CO-3	0.67	—	—

* SO = "soft, oily" fish
CO = control fish
** including liver
— Not determined

Results and Discussion

The lipid percentages, lipid compositions and the fatty acid compositions of the various cod samples are given in Tables I, II and III respectively.

The Iatroscan flame ionization detector area responses for fillets (Table II) were heavily biased by the dominance of the phospholipids. Conversely, lipids of the viscera and stomachs were dominated by triglycerides. They are therefore reported simply as area % since normal correction procedures (Parrish and Ackman 1985) would have been very difficult to apply.

An unexpected result was the very low lipid content of the viscera of two soft cod (Table I). It should be noted that the lipid content in the viscera is variable, depending mainly on the nutritional and reproductive status of the fish. The viscera did not include ripe or ripening gonads and therefore the liver was quantitatively the most important component. The liver is normally 30-50% fat and plays an important role in the "condition" of the fish (Jangaard et. al. 1967a). As expected the visceral lipids from the two control samples were mostly triglycerides, whereas those of the soft oily cod showed only about 90% triglycerides, the rest being mostly phospholipids (Table II). In a study of Nova Scotian cod livers (O'Keefe, 1984) only 3 of 71 livers had less than 25% lipids.

The variations in the stomach lipid compositions (Table II) are apparently due to the different types of food in the stomachs. The lipid content in the stomachs were low and varied from 0.98 to 4.82%. Visual examination of the soft oily cod (SO-2 and SO-4) showed some undigested clams and fish bones in their stomachs. The stomach contents of the control fish could not be identified by visual examinations. They are normally fed chopped herring, supplemented with beef liver.

Table II Lipid composition of the cod samples as determined by the Iatroscan TLC/FID

Sample	Iatroscan Area % *					
Fillets	SE	FFA**	FFA†	TG	CHL	PL
Dressed SO-1	—	TR	TR	TR	1.4	98.6
Round SO-2	TR	TR	TR	TR	5.4	94.6
Dressed SO-3	TR	TR	TR	TR	4.3	95.7
Round SO-4	—	—	—	—	TR	100
Round CO-1	—	TR	TR	TR	4.7	95.3
Round CO-2	—	TR	—	TR	3.5	96.5
Dressed CO-3	—	—	—	—	1.7	98.3
Viscera						
Round SO-2	—	—	—	90.8	TR	9.2
Round SO-4	—	—	—	90.4	TR	9.6
Round CO-1	—	—	—	100	—	—
Round CO-2	—	—	—	100	TR	—
Stomach						
Round SO-2	—	1.7	2.6	1.2	15.5	78.9
Round SO-4	—	TR	TR	83.4	2.7	13.9
Round CO-1	—	—	TR	95.1	TR	4.9
Round CO-2	—	3.3	4.5	56.7	4.1	29.5

* The Iatroscan TLC/FID responses were not corrected to w/w%. TR, trace; SE, steroid esters; FFA, free fatty acids; TG, triglyceridecs; CHL, cholesterol; PL, phospholipid.

** Primarily saturated acids (e.g. 16:0).

† Primarily polyunsaturated acids (e.g. 22:6n3).

Table III Fatty acid composition of total lipids of selected cod samples in w/w %.

Fatty* Acid	Fillet SO-2	Fillet SO-4	Fillet CO-2	Viscera SO-2	Stomach SO-2
14:0	2.6	2.9	6.0	7.9	6.0
Iso 15:0	—	—	—	0.7	—
15:0	0.7	0.6	0.7	0.9	1.2
Iso 16:0	—	—	—	0.3	—
Anteiso 16:0	—	—	—	0.3	—
16:0	29.2	32.0	24.1	17.9	21.6
17:0	0.3	0.2	0.3	0.3	0.8
Iso 18:0	0.2	0.1	0.2	0.2	0.3
18:0	3.8	3.9	2.6	2.0	5.4
19:0	0.2	0.2	0.1	—	0.2
20:0	—	—	<0.1	<0.1	0.1
Total saturates	37.0	39.9	34.0	30.5	35.6
16:1n7	2.4	2.4	5.2	12.3	5.8
16:1n5	0.5	0.4	0.6	0.4	0.4
18:1n11	—	—	—	—	0.3
18:1n9	6.5	5.7	12.4	12.6	8.3
18:1n7	4.0	2.8	3.0	5.1	3.2
18:1n5	0.3	0.3	0.5	0.4	0.3
20:1n11	0.3	0.2	0.7	1.3	3.2
20:1n9	1.4	1.4	4.0	5.9	2.6
20:1n7	0.1	0.1	0.1	0.5	0.3
22:1n5	—	—	—	0.1	0.1
22:1n11 + 13	0.2	0.6	1.0	0.5	0.3
22:1n9	<0.1	—	0.1	0.5	0.3
22:1n7	—	—	—	0.1	0.1
24:1n9	—	0.1	0.3	0.2	0.2
Total monoenes	15.7	14.0	27.9	42.8	27.2
16:2n6	—	—	—	—	0.5
16:2n4	0.1	0.2	0.4	0.7	1.1
18:2n6	1.1	0.7	2.0	1.3	0.9
18:2n4	0.1	0.1	0.1	0.2	0.2
20:2NMID	—	—	—	—	0.8
20:2n6	0.1	0.1	0.1	0.2	0.2
Total dienes	1.4	1.1	2.6	2.4	3.7
16:3n4	0.3	0.1	0.2	0.4	—
18:3n6	0.1	0.1	0.1	0.1	0.2
18:3n4	0.1	0.1	0.1	0.2	0.2
18:3n3	0.3	0.2	0.3	0.7	0.2

The level of fillet lipids in the present study fell within the range of values expected (0.5-0.7%) for Atlantic cod, *Gadus morhua* (Jangaard et. al. 1967a; Addison et. al. 1968). There was no apparent difference in the fillet lipid levels between the control and the soft oil samples or in relation to visceral lipid.

The lipid class compositions for the fillets (Table II) are all generally similar, except for one soft oily cod (SO-4) which showed even more phospholipid than in the other samples. Probably this finding was correlated with a low visceral lipid. Phospholipid

Table III continued

Fatty Acid	Fillet SO-2	Fillet SO-4	Fillet CO-2	Viscera SO-2	Stomach SO-2
20:3n6	—	—	0.1	<0.1	0.1
20:3n3	0.1	0.1	<0.1	0.1	0.1
Total trienes	—	—	—	0.1	—
16:4n3	—	—	0.2	0.5	0.2
16:4n1	—	—	0.2	0.5	0.2
18:4n3	0.4	0.3	0.4	1.5	0.6
18:4n1	0.1	0.1	0.1	0.2	0.1
20:4n6	1.7	1.4	2.5	0.4	2.2
20:4n3	0.3	0.3	0.3	0.4	0.3
22:4n6	—	—	0.4	—	0.2
Total tetraenes	2.5	2.1	4.0	3.1	3.6
18:5n3	—	—	—	0.1	2.5
20:5n3	17.1	16.9	12.3	8.1	12.1
21:5n3	0.3	0.5	0.3	0.3	0.6
22:5n6	0.6	0.4	0.3	0.2	0.4
22:5n3	0.8	1.4	1.3	1.0	1.6
Total pentaenes	18.8	19.2	14.2	9.7	17.2
22:6n3	24.0	23.6	16.5	10.3	12.5
Calc. iodine value	224.8	220.9	188.1	149.9	179.6

* Fatty acid notation indicates: Number on left of colon is the number of carbon atoms in the fatty acid chain; on the right of the colon, the number of ethylenic bonds; the number to the right of "n" is the position of the ethylenic bond nearest to the terminal methyl group.

was the major lipid component in all the fillet samples, and sterol was the only other quantitatively important lipid component. Triglyceride was found in small amounts in all samples and was found to be accompanied by an equal amount of diacyl glyceryl ethers (Ratnayake et al., 1986), hitherto not reported for cod flesh lipids. It is concluded that there was possibly more lipid in the fillet from the soft oily cod than the controls, but the small number of samples precluded a definitive comparison.

The fatty acid profiles of five cod lipid samples are given in Table III. The fatty acid compositions of the fillets from the two soft oily cod samples (SO-2 and SO-4) were basically similar to those published by Jangaard et. al. 1967b and by Addison et. al. 1968, in studies on the flesh lipids of Atlantic cod, but were different in important details. Palmitic acid (16:0) at 29.2 and 32.0% was much higher than literature values (ca. 20%). Conversely octadecenoic acids (18:1) at 10.8 and 8.8% respectively were less than previous totals of 12-13%. Of the two major polyunsaturated acids, 20:5n3 at about 17% was almost exactly the same as in previous reports, whereas 22:6n3 at about 24% was less than previous reports of 30-33% from the two independent studies.

Unexpectedly the fatty acid composition of the lipids from the control fish differed from previous reports and was also different from the two soft oily cod. According to the Addison et. al. (1968) results, the major fatty acids of male cod flesh are 16:0, 18:1, 20:5n3 and 22:6n3 with weight percentages of 19.6, 13.8, 17.0 and 29.8 respectively. From the Table III results, it is clear that the percentages of the above four major fatty acids from the lipids of the control cod are distinctly different. Especially, the control cod flesh lipid showed relatively low proportions of 20:5n3 and 22:6n3 and correspondingly was enriched with monoethylenic fatty acids. Unfortunately a sample of only one fish is always suspect (Takahashi et. al. 1985) and a more thorough investigation is indicated. It should be noted that Jangaard et. al. (1967b) averaged 12 seasonal samples and Addison et. al. published averages from four fish of each sex. Whether aquarium-held cod are reliable comparison samples for lipid and fatty acid studies is an open question.

The fatty acid composition of the viscera of SO-2 was similar to that of normal Atlantic cod livers (Jangaard et. al. 1967b; Addison et. al. 1968) with 16:0, 16:1, 18:1, 20:1, 22:1, 20:5n3, and 22:6n3 as major fatty acids. A novel fatty acid, 20:2 $\Delta 5$, $\Delta 13$ was tentatively identified from the stomach of a soft oily cod (SO-2). This and other non-methylene-interrupted fatty acids are minor fatty acids among those of Atlantic molluscs and other invertebrates (Paradis and Ackman 1977). In this connection *Limacina helicina*, a mollusc, is a known factor in the food web transfer of *dimethyl-2-carboxyethyl sulfonium chloride* and its breakdown product, dimethylsulfide, to economically valuable fish such as cod (Ackman et. al. 1967; Botta et. al. 1985) or mackerel (Ackman et. al. 1972). The acrylic acid accompanying the dimethylsulfide could lead to protein breakdown post-mortem but this line of investigation was not pursued. Protease activity (Ando et. al., 1986) seems more probable. These enzymes are known to produce a "jellied" condition in American plaice *Hippoglossoides platessoides* (Templeman and Andrews 1956), or in other species (Konagaya 1984).

These preliminary results suggest that although the lipid content in fillets of "soft cod" is similar to that reported in the literature for normal fish, the visceral lipid is abnormally low. There also appears to be abnormalities in the fatty acid composition of fillets of "soft cod", but substantiation of these inferences requires detailed studies on large samples of control fish and of "soft cod".

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References

Ackman, R.G. 1981. Flame ionization detection applied to thin-layer chromatography on coated quartz rods. In *Methods in Enzymology* (ed J.M. Lowenstein). Academic Press, New York, pp. 205-252.

Ackman, R.G. 1986. WCOT (capillary) gas-liquid chromatography. In *Analysis of Fats and Oils* (eds. R.J. Hamilton and J.B. Russell). Elsevier Applied Science Publishers, London, pp. 137-206.

Ackman, R.G. and **Eaton, C.A.** 1971. Investigation of the fatty acid composition of oils and lipids from the sand launce *Ammodytes americanus* from Nova Scotia waters. *J. Fish. Res. Board Can.* 28:601-606.

Ackman, R.G., Hingley, J. and **May, A.W.** 1967. Dimethyl-beta-propiothetin and dimethyl sulfide in Labrador cod. *J. Fish. Res. Board Can.* 24:457-461.

Ackman, R.G., Hingley, J. and **MacKay, K.T.** 1972. Dimethyl sulfide as an odor component in Nova Scotia fall mackerel. *J. Fish. Res. Board Can.* 29:1085-1088.

Ando, S., Hatano, M. and **Zama, K.** 1986. Protein degradation and protease activity of chum salmon (*Oncorhynchus keta*) muscle during spawning migration. *Fish Physiology and Biochemistry,* 1:17-26.

Addison, R.F., Ackman, R.G. and **Hingley, J.** 1968. Distribution of fatty acids in cod flesh lipids. *J. Fish. Res. Board Can.* 25:2083-2090.

Bligh, E.G. and **Dyer, W.J.** 1959. A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.* 37:911-917.

Botta, J.R., Byrne, E.A. and **Squires, B.E.** 1985. Utilization of Atlantic Cod (*Gadus morhua*) Judged to Have "Blackberry" Odor. *Can. Tech. Rep. of Fish Aq. Sci.* No. 1383, 11 pages.

Holmer, G. 1967. Studies over Danske Fiskoliers Sammensaetning. Fiskeriministeriets Forsogslaboratorium og Afd. for Biokemi og Ernaering. D.T.H. Kobenhaven, 150 p.

Jangaard, P.M., Brockerhoff, H., Burgher, R.D. and **Hoyle, R.J.** 1967a. Seasonal changes in general condition and lipid content of cod from inshore waters. *J. Fish. Res. Board Can.* 24:607-612.

Jangaard, P.M., Ackman, R.G. and **Sipos, J.C.** 1967b. Seasonal changes in fatty acid composition of cod liver, flesh, roe, and milt lipids. *J. Fish. Res. Board Can.* 24:613-627.

Konagaya, S. 1984. Studies on jellied meat of fish, with special reference to that of yellowfin tuna. Bull. Tokai Reg. Fish. Lab. No. 114 (Abstract in English of 5 pages).

Morrison, W.R. and **Smith, L.M.** 1964. Preparation of fatty acid methyl esters and dimethyl acetals from lipids with boron fluoride-methanol. *J. Lipid Res.* 5:600-608.

O'Keefe, S.F. 1984. Vitamin A, D and E in Nova Scotia Cod Liver Oils. M.Sc. Thesis, Technical University of Nova Scotia.

Paradis, M. and **Ackman, R.G.** 1977. Potential for employing the distribution of anomolous non-methylene-interrupted dienoic fatty acids in several marine invertebrates as part of food web studies. *Lipids* 12:170-176.

Parrish, C.C. and **Ackman, R.G.** 1985. Calibration of the Iatroscan Chromarod system for marine lipid class analyses. *Lipids* 20:521-530.

Ratnayake, W.M.N., Timmins, A., Ohshima, T. and **Ackman, R.G.** 1986. Mass spectra of fatty acid derivatives of isopropylidenes of novel glyceryl ethers of cod muscle and of phenolic acetates obtained with the Finnigan MAT ion trap detector. *Lipids* 21:518-524.

Takahashi, K., Ichioka, K., Hatano, M. and **Zama, K.** 1985. Seasonal variation of sardine (*Sardinops melanosticta*) muscle lipids and other components. *Bull. Fac. Fish., Hokkaido Univ.* 36:248-257.

Templeman, W. and **Andrews, G.L.** 1956. Jellied condition in the American plaice *Hippolossoides platessoides* (Fabricius). *J. Fish. Res. Board Can.* 13:147-182.

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ERROR BOUND STRATEGIES FOR A NEW HULL PLATE EXPANSION PROCEDURE

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An improved version of a recently developed (Clements and Leon, 1986) isometric mapping procedure is presented. This algorithm employs a variable step differential equation solver (ODES) in conjunction with an adaptive quadrature routine (AQR). Criteria for choosing appropriate error tolerances for the numerical implementation of the algorithm are presented. An application is briefly discussed.

Une version améliorée d'un procédé d'application isométrique développé récemment est presentée. Cet algorithme utilise une routine de résolution d'équations différentielles a étape variable avec une routine adaptive de quadrature. Les critères à considérer en choisissant les tolérances admissibles pour l'application numérique de cet algorithme sont discutés. Une application est brièvement discutée.

Introduction

The availability of fast, economical computing capability provides small manufacturing operations with the potential for substantially automating and improving existing design procedures and production techniques. This development has permitted the direct application of advanced mathematical methods and results to the solution of problems which hitherto have been avoided because of the computational complexity involved. The implementation of this mathematical analysis in the form of computer programs yields what is often referred to as scientific or engineering software.

In the construction of steel ship hulls (Fig 2), for example, the standard procedure is to loft (from preliminary design plans) the vessel at full scale often using an oak stick called a spline to manually fair or "smooth" each hull line. The frames are constructed from the offset data obtained, set vertically in place and tack-welded together. The steel plate is then measured, cut and welded to the frames in sections. Sometimes the hull plating is difficult and time consuming since one cannot predict if the plate can be shaped to conform exactly to each frame member with simple unidirectional bending. This is particularly true in the areas of large curvature such as the bow where the accepted practice is to patch with small triangular plate sections.

Clearly there is a requirement for a computer system which could use preliminary hull design data to mathematically define and fair all hull lines; determine if the resulting hull surfaces are developable and, if not, automatically modify the existing hull lines to ensure developability; generate graphic displays of waterlines, buttock lines and frame stations and use these to compute elementary hydrostatics, and to generate detailed tables of offsets for both the required frame members and the developable hull surfaces mapped (expanded) onto a flat plane surface (See Fig 3).

This last step eliminates the full scale lofting and manual fairing and permits the precutting from a plane pattern of single hull plate sections of 50 feet or more in length and ensures that the plate will fit at all points of each frame member with unidirectional bending. The use of developable hull forms in shipbuilding offers the advantages of lower cost and faster and simpler construction techniques (Clements and Leon (1986) and Clements (1981)). Indeed, the isometric mapping of developable surfaces or "plate expansion" is a basic problem in many other manufacturing and construction programs. The engineering system specifications listed were met by SYSTEM DEVHULL (Clements 1981) which consists of nineteen component programs and approximately 10,000 lines of FORTRAN source code. In this paper the mathematical analysis and its application will be discussed for a specific improvement to the plate expansion component of the system.

In Differential Geometry a surface **S** in three dimensional Euclidean space $\mathbf{R}^3$ is called a ruled surface if it contains a one parameter family of straight lines called generators or ruling lines **r** which can be chosen as coordinate curves on the surface. A developable surface is a ruled surface defined by nonintersecting generators which has the same tangent plane at all points of each generator (Fig 1). We shall be concerned here with developable surfaces which can be represented in the form

$$\mathbf{S}(s, t) = \mathbf{f}(s) + t\mathbf{r}(a), \qquad a \leq s \leq b, 0 \leq t \leq 1.$$

where **f** and **r** are twice continuously differentiable vector functions in $\mathbf{R}^3$. The term "developable" refers to the property that by a succession of small rotations about each of the generating lines the surface can be laid flat or developed onto a plane without stretching or tearing. That is, it can be mapped isometrically (and isogonally) onto a subset of $\mathbf{R}^2$. Conversely, a plane surface material can be shaped into a developable surface with only simple unidirectional bending along the generating lines.

In Clements and Leon (1986) and Clements (1984) a fast and accurate algorithm was derived to accomplish isometric mapping based on the relationship between the ruling lines $\mathbf{r}(s)$ generating the developable surface **S** and one additional geodesic $\mathbf{g}(s)$ constructed within the surface as the solution of the nonlinear second order ordinary differential equation.

$$\ddot{\mathbf{g}}(s) \cdot (\mathbf{g}(s) x \mathbf{n}) = 0, a \leq s \leq b, \tag{1}$$

where s is the real parameter, $\cdot$ and x are the usual scalar and vector products respectively, $\dot{} \equiv d/ds$, and **n** is the unit normal to **S** at $\mathbf{g}(s)$. The mapping procedure $m \colon r \rightarrow \mathbf{R}$ is defined in terms of the ruling line lengths $\|\mathbf{r}(s)\|$, the arclengths along $\mathbf{g}(s)$ and the angles of intersection of $\mathbf{r}(s)$ and $\mathbf{g}(s)$. Since $\mathbf{g}(s)$ is a geodesic in the developable surface **S**, its image under the isometric mapping must be a straight line in the plane and, for simplicity, is taken to be the positive real x—axis (Fig 1). Each ruling line is then mapped into the corresponding plane coordinate line **R** in the developed surface.

The solution process requires the numerical solution of the coupled integro-differential equation system consisting of (1) and

$$I_k = {}^{s_k}\!\int_{s_{k-1}} \|\dot{g}(s)\| ds, \ k = 1, \ldots, N, \tag{2}$$

where $P_N = \{a = s_0 < s_1 < \ldots < s_N = b\}$ is a partition of [a, b] chosen initially by the user to conform to display, cutting or other requirements. Equations (1) and (2) are coupled since each time a quadrature routine is called to approximate the integral in (2), the ordinary differential equation (1) must be solved for $\dot{\mathbf{g}}(s)$ at those points in $[s_{k-1}, s_k]$ required by the quadrature routine.

The practical difficulty lies in choosing the error tolerances, ε_{Dk} and ε_{Dk}, to be assigned to the numerical routines used to compute the solutions of (1) and (2) respectively so that it is assured that $| \|\dot{\mathbf{g}}(s)\| - J_N | < \varepsilon_T$ for some specified total absolute error tolerance ε_T. That is, which will ensure that the maximum error in the determination of the total length of $\mathbf{g}(s)$ is less than some user specified tolerance ε_T.

The object here is to derive a rational and efficient strategy for the choice of ε_{Qk} and ε_{Dk} in the solution of (1) and (2), to describe an improved version of the mapping algorithm (Clements 1984) incorporating both a variable stepsize differential equation solver (ODES) and an adaptive quadrature routine (AQR) and to discuss briefly an application.

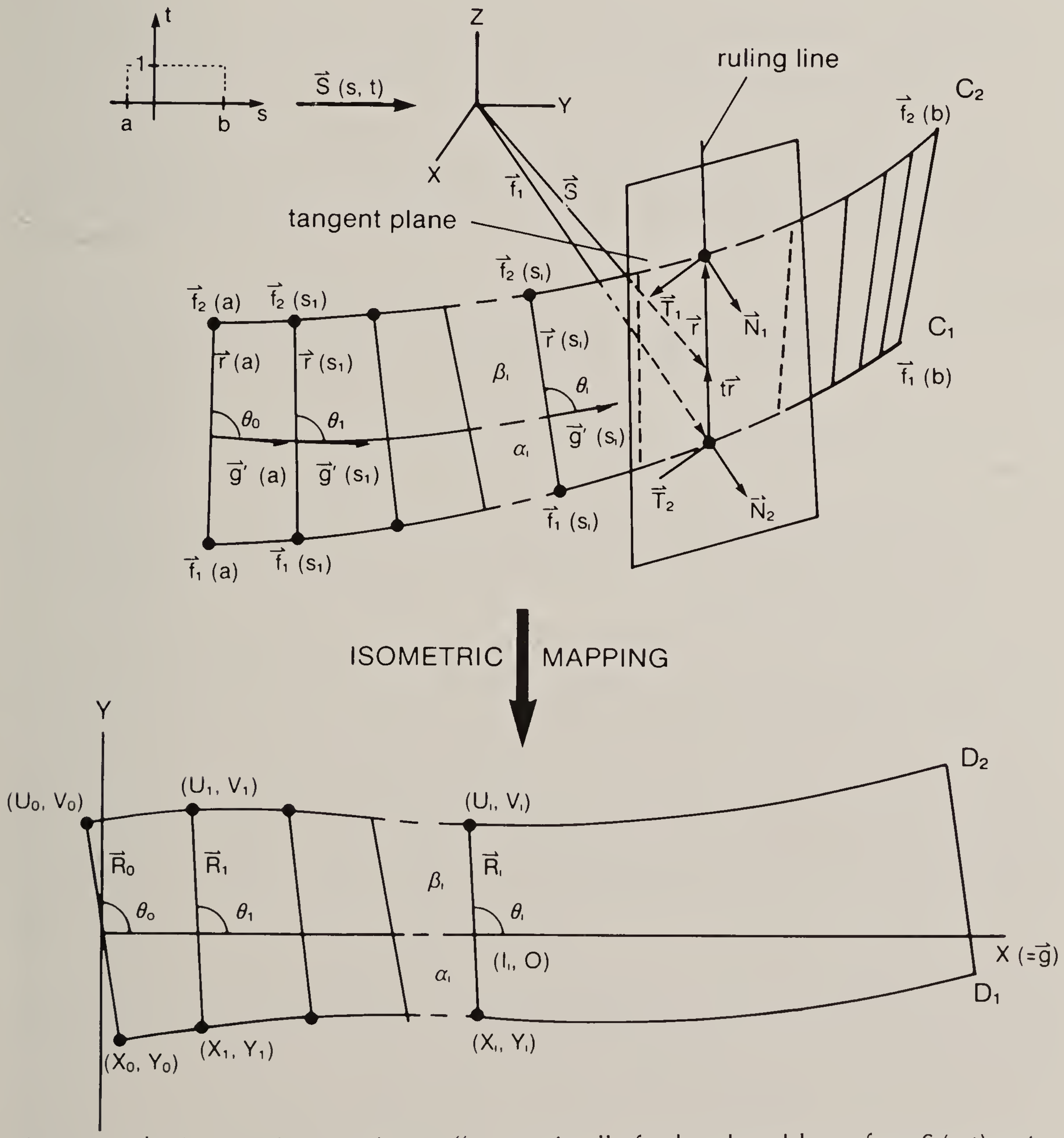

Fig 1 The isometric mapping or "expansion" of a developable surface S (s, t) onto the x, y plane. In the figure vectors are denoted by a superscript arrow rather than bold-face as in the text.

Definitions and Results

Let $C^k\ [a, b] \equiv \{x(s): x$ is k times continuously differentiable for all s in $[a, b]\}$. Curves in $\mathbf{R}^3$ will be denoted by

$$C: f = x(s)i + y(s)j + z(s)k,\ s \ \varepsilon\ [a, b],$$

with components $x(s)$, $y(s)$, and $z(s)$, and Euclidean norm $\|f\| = (x^2(s) + y^2(s) + z^2(s))^{1\ 2}$. In Fig 1 vector functions are denoted by f rather than by **f** as in the text. In what follows, it is assumed that the developable surface **S** is given by ([4])

$$\mathbf{S}(s, t) = \mathbf{f}_1(s) + tr(s),\ \dot{\mathbf{f}}_1(s) \times \mathbf{r}(s) \neq 0,\ s\ \varepsilon\ [a, b],\ t\ \varepsilon\ [0, 1], \tag{3}$$

where

(i) $\mathbf{f}_1(s) = x_1 i + y_1 j + z_1 k$, with $x, y, z\ \varepsilon\ C^2\ [a, b]$,

(ii) $r(s) = r_1(s)i + r_2(s)j + r_3(s)k$, with $r_i\ \varepsilon\ C^2\ [a, b]$, $i = 1, 2, 3$,

(iii) each point of **S** corresponds to only one ordered pair (s, t).

Thus **S** is bounded by the curves C_1: $\mathbf{f}_1(s)$ and C_2: $\mathbf{f}_2(s) = \mathbf{f}_1(s) + \mathbf{r}(s)$ and the ruling lines $\mathbf{r}(a)$ and $\mathbf{r}(b)$. In the actual application of the mapping procedure to hull plate expansion, C_1 and C_2 represent the chine curves defining the developable surfaces as in Fig 2.

Remark

Each ruling line $\mathbf{r}(s)$ in **S** can be computed as $\mathbf{r}(s) = \mathbf{f}_2(s^*) - \mathbf{f}^1(s)$ for fixed $s\ \varepsilon\ [a, b]$ where $s^*\ \varepsilon\ [a, b]$ is the solution of the fixed point equation (Clements 1984)

$$G\ (s^*) = \det(\dot{\mathbf{f}}_1(s), [\mathbf{f}_2(s^*) - \mathbf{f}_1(s)], \dot{\mathbf{f}}_2(s^*)) = 0, \tag{4}$$

Equation (4) is used because of the result that a ruled surface given by (3) is developable if and only if $\det\ (\dot{\mathbf{f}}_1(s), \mathbf{r}(s), \dot{\mathbf{r}}(s)) = 0$ (Kreyszig 1959). It is assumed here that this calculation has already been completed and that $\mathbf{r}(s)$ is known for every fixed s in [a, b].

The geodesic curvature κ_g of a curve C: $\mathbf{g}(s)$ in a surface **S** is given by

$$\kappa_g(s_0) = \det\ (\dot{\mathbf{g}}, \ddot{\mathbf{g}}, n) = -\ddot{\mathbf{g}} \cdot (\dot{\mathbf{g}} \times \mathbf{n}),$$

where **n** is the unit normal to the surface **S** at $\mathbf{g}(s_0)$. We also note that $\mathbf{g}(s)$ on **S** is a geodesic if and only if $\kappa_g = 0$ and is either a straight line or its principal normal coincides with the surface normal at the point s. Since a geodesic $\mathbf{g}(s)$ in **S** joining any two points of **S** not on the same generator can be represented in the form

$$\mathbf{g}(s) = \mathbf{f}_1\ (s) + t^*\ (s)\ \mathbf{r}(s) \tag{5}$$

for some twice continuously differentiable function (Clements & Leon 1984) $\mathbf{g}(s)$ and $\dot{\mathbf{g}}(s)$ can be obtained by solving (1) for $t^*(s)$ and $\dot{t}^*\ (s)$, or equivalently by solving the first order system

$$\dot{u}_1(s) = u_2(s), \qquad a \leq s \leq b,$$

$$\dot{u}_2(s) = F(u_1(s), u_2(s)), \qquad a \leq s \leq b, \qquad (6)$$

$$= - \frac{\ddot{\mathbf{f}} \cdot (\dot{\mathbf{g}} \times \mathbf{n}) + u_1 \ddot{\mathbf{r}} \cdot (\dot{\mathbf{g}} \times \mathbf{n}) + 2u_2 \dot{\mathbf{r}}(\dot{g} \times \mathbf{n})}{\mathbf{r} \cdot (\mathbf{g} \times \mathbf{n})},$$

for $u_1(s) = t^*(s)$ and $u_2(s) = \dot{t}^*(s)$ at each s in [a, b] where $\mathbf{n}(s) = \mathbf{r}(s) \times \mathbf{T}_1(s)$ is a normal to the developable surface **S** at **g**(s) and $\mathbf{T}_1(s) = \dot{\mathbf{f}}_1(s)/\|\dot{\mathbf{f}}_1\|$. Calculation of the Lipschitz constant for F in (6) shows that the system is solvable by standard numerical methods (Dahlquist and Bjorck 1969) provided $\mathbf{r} \cdot (\dot{\mathbf{g}} \times \mathbf{n})$ stays bounded away from zero. The numerical solution of equation (6) requires some starting values at s = a and involves the computation of $\mathbf{f}_1, \dot{\mathbf{f}}_1, \ddot{\mathbf{f}}_1, \mathbf{r}, \dot{\mathbf{r}}$, and $\ddot{\mathbf{r}}$. For simplicity the starting values are taken to be

$$u_1(a) = .5, \quad u_2(a) = 0 \qquad (7)$$

or the midpoint of **r**(a) as indicated in Fig 1.

Once (1), (2) have been solved, the image of each $\mathbf{r}(s_i)$, $i = 0, \ldots, N$, is determined by computing as in Fig 1.

$$\alpha_i = t^*(s_i)\,\|\mathbf{r}(s_i)\|,$$

$$\beta_i = (1 - t^*(s_i))\,\|\mathbf{g}(s_i) - \mathbf{f}_2(s_i)\|. \qquad (8)$$

$$\theta_i = \cos^{-1}\left(\frac{\dot{\mathbf{g}}(s_i) \cdot \mathbf{r}(s_i)}{\|\dot{\mathbf{g}}(s_i)\| \cdot \|\mathbf{r}(s_i)\|}\right) \text{ for } i = 0, \ldots, N,$$

Then

$$(X_i, Y_i) = (J_i - \alpha_i \cos\theta_i, -\alpha_i \sin\theta_i),$$

$$(U_i, V_i) = (J_i + \beta_i \cos\theta_i, \beta_i \sin\theta_i), \qquad (9)$$

$$J_i = \sum_{j=1}^{i} l_j,$$

$$\mathbf{R}_i = (U_i - X_i, V_i - Y_i)$$

and the surface **S** bounded by $\mathbf{r}(s_0)$ and $\mathbf{r}(s_N)$ has been mapped isometrically onto that portion of the plane bounded by $\mathbf{R}_0$, R_N and (X_i, Y_i), (U_i, V_i), $i = 0, \ldots, N$.

The calculations θ_i, $\cos\theta_i$ and $\sin\theta_i$ in (8) and (9) are only required at each partition point and can be computed using double precision arithmetic. Consequently, it is assumed that roundoff errors in individual arithmetic operations and evaluations of the elementary special functions are negligible when compared to the errors propagated due the use of inexact function values in the solution of (2). Consequently, it is assumed that the errors in evaluating θ_i, $\cos\theta_i$ and $\sin\theta_i$ do not contribute significantly to the global error in the mapping procedure.

It is assumed that the geodesic **g**(s) stays within the boundaries of the developable surface, and that $r \cdot (\dot{\mathbf{g}} \times \mathbf{n})$ stays bounded away from zero. Hence, the differential equations given by (6) are solvable everywhere on [a, b]. One method to ensure this is to restart the procedure with new initial values at that point on **g** where it crosses the boundary curves C_1 or C_2, or where $\mathbf{r} \cdot (\dot{\mathbf{g}} \times \mathbf{n})$ becomes sufficiently small. However, to avoid unnecessary complexity, these details are not included in the statement of the mapping algorithm given here.

The Mapping Algorithm:

1) Choose P_N and ε_T.

2) Choose an adaptive quadrature routine for evaluating I_k in (9) accurate to a specified ε_{Qk} for each k = 1, ..., *N*.

3) Choose an accurate variable step differential equation solving routine where each evaluation of t* and $\dot{t}$* required in the integration routine is computed accurate to a specified ε_{Dk}, for each k = 1, ..., *N*.

4) Compute α_0, β_0 and θ_0 as in (8) to obtain

$$(X_0, Y_0) = (-\alpha_0 \cos \theta_0, -\alpha_0 \sin \theta_0),$$

$$(U_0, V_0) = (\beta_0 \cos \theta_0, \beta_0 \sin \theta_0),$$

and

5) For each i = 1, ..., *N* compute I_i, α_i, β_i, and θ_i as in (8) and (9) using the differential equation solver to evaluate $\mathbf{g}$ and $\dot{\mathbf{g}}$ at the points required by the quadrature routine, to obtain the coordinates of the ruling line end points of **S** mapped isometrically

$$(X_i, Y_i) = (J_i - \alpha_i \cos \theta_i, -\alpha_i \sin \theta_i),$$

$$(U_i, V_i) = (J_i + \beta_i \cos \theta_i, \beta_i \sin \theta_i),$$

onto the plane.

Choosing the error tolerances

Assume a tolerance ε_T, is given, which is to bound the total error in the numerical process. On the assumption that the calculations are equally difficult in each subinterval $[s_{k-1}, s_k]$ we bound the total error committed in evaluating I_k by

$$\varepsilon_T \frac{(s_k - s_{k-1})}{(b - a)} = \varepsilon_k \tag{10}$$

for each k. It is also assumed that an Adaptive Quadrature Routine (AQR), based on a quadrature formula with degree of precision *d*, will be used to evaluate (2), and that an appropriate Ordinary Differential Equation Solver (ODES), based on a method of order *r*, will be used to solve (1) at the points required by the AQR. Given ε_k the problem is to determine the tolerances, ε_{Qk} and ε_{Dk}, to be given to the AQR and the ODES respectively. As in Fritsch, Kahaner and Lyness (1981) it is assumed throughout that both the AQR and the ODES are completely reliable, that is, they will always return results which are accurate to within the tolerances specified, that the AQR will perform its computations in the same order with polluted data as with exact data, and that all calls to the ODES are of the same level of difficulty.

The problem is one of interfacing two software packages in an efficient and reliable manner. This problem has been considered recently in Fritsch, Kahaner and Lyness (1981) (under the same assumptions as above), where the scenario of an AQR using results obtained by a second AQR was considered. The analysis given here is motivated by this work.

Denote by $\phi(f)$ the AQR applied to a function *f*, by $I(f)$ the correct integral of *f*, and by f_c the numerical approximation to the function *f* which is actually computed by the ODES, here denoted by ψ. Given ε_k, it is then required that

$$|I(f) - \phi(f) + \phi(f) - \phi(f_c)| \leq |I(f) - \phi(f)| + |\phi(f) - \phi(f_c)| \leq \varepsilon_k.$$

The error can now be seen to be made up of two distinct components: $|I(f) - \phi(f)|$, due to approximating I by ϕ (assuming that correct function evaluations are available to ϕ), and $|\phi(f) - \phi(f_c)|$, due to incorrect function evaluations being made available to ϕ. Thus divide ε_k, the total error tolerance for the entire numerical procedure of evaluating I_k, into two components, ε_{Qk} and ε_{ODEk} with

$$\varepsilon_k = \varepsilon_{Qk} + \varepsilon_{ODEk},$$

$\varepsilon_{Qk} \geq |I(f) - \phi(f)|$ being the tolerance given to the AQR, and ε_{ODEk} bounding the errors due to obtaining inaccurate values of f. Thus the tolerances given in each call to ψ, namely ε_{Dk}, depend on ε_{ODEk}, although they will not normally be equal to ε_{ODEk}. The interpretation of ε_{ODEk} is that it reflects the total error accummulated due to the calls to ψ made by ϕ.

Assume that the AQR uses a basic Quadrature Formula $Q_B(f) = \Sigma\, w_j f(x_j)$ and has some strategy for applying Q_B to some sequence of subintervals in the interval of integration. Q_B, when applied over an interval of unit length will have a condition number $C_B = \Sigma |w_j|$. It follows by linearity of the quadrature process that if Q_B is applied over an interval of length H, the condition number of the integration will be HC_B. Now define C_Q to be the condition number of ϕ applied over the interval (s_{k-1}, s_k). By linearity of the quadrature process, we have $C_Q \leq (s_k - s_{k-1})C_B$. In fact C_Q will equal $C_B H$ unless Q_B uses both endpoints of the interval of the integration and the corresponding coefficients are of opposite sign. Note that the method by which ϕ determines the order in which Q_B will be applied to the subintervals does not affect the previous comments.

Now assume that the maximum error in any call to ψ is ε_{Dk}. It then follows that the maximum error in the numerical process due to ϕ using inexact data from ψ is bounded by $C_Q\, \varepsilon_{Dk}$. Thus, from

$$\varepsilon_k = \varepsilon_{Qk} + \varepsilon_{ODEk} = \varepsilon_{Qk} + (s_k - s_{k-1})\, C_B\, \varepsilon_{Dk} \tag{11}$$

it follows that, once ε_{ODEk} is specified, ε_{Dk} should be chosen as

$$\varepsilon_{Dk} = \frac{\varepsilon_{ODEk}}{(S_k - s_{k-1})\, C_B} \tag{12}$$

If the condition number of ϕ is specified in more detail (see, for example, Stoer and Bulirsch 1980) then a similar analysis may be carried out. However, since this leads to different tolerances being specified for each call to ψ, (that is, ψ would have to be solved from the initial point a on every call) and also leads to some restrictions on the type of AQR which may safely be used, we shall not pursue this possibility further here.

There are two generic ways in which an AQR can be constructed (Fritsch, Kahaner and Lyness, 1981), it can either be based on a local error control strategy (LG) or it can be based upon some form of global error control strategy (GE). The essence of a LE method is that the procedure moves through the interval of interest, say from left to right, and locally acts upon a subinterval. It does not progress to the next subinterval until the result obtained for the subinterval under consideration is considered to be sufficiently (locally) accurate. Consequently, when the procedure is complete, since all the local errors are believed to be sufficiently small, the total error of the procedure is believed to be within the specified tolerance. In contrast, a GE method is always able to consider one of many subintervals, and always chooses to work on that subinterval which has the worst error estimate. Thus a GE method examines the subintervals in an order very difficult to predict before the computation is begun. A

GE method exists when the sum of all the local errors is believed to be less than the prescribed tolerance. It is recommended (Fritsch, Kahaner and Lyness 1981) that a global error control strategy AQR be used if it is felt that the AQR may encounter some difficulty since, in contrast to a local error control strategy AQR, a global error AQR may have the opportunity to recover from dealing with a subinterval with a large error estimate by considering other subintervals.

Now consider the question of choosing $\varepsilon_{\mathrm{ODE}k}$ (and thus $\varepsilon_{\mathrm{D}k}$) and $\varepsilon_{\mathrm{Q}k}$ to minimize the computational cost, given the requirement $\varepsilon_k = \varepsilon_{\mathrm{Q}k} + \varepsilon_{\mathrm{ODE}k}$. The error when $\mathrm{Q_B}$ is applied over an interval of length H depends upon H^{d+2}. Thus, if (a, b) is partitioned into subintervals of length H, the overall error when using $\mathrm{Q_B}$ in a compounded manner will be $O(H^{d+1})$. Measuring work in terms of the number of subintervals (which is proportional to the number of integrand evaluations required) of equal length to which $\mathrm{Q_B}$ should be applied to achieve a given tolerance, it follows that the cost of using ϕ with tolerance $\varepsilon_{\mathrm{Q}k}$ is proportional to $\varepsilon_{\mathrm{Q}k}^{-1/(d+1)}$. Now consider the amount of work involved in a call to ψ. Since ψ is based on a method, either multistep or Runge-Kutta, which has local order r, and thus local error $O(H^{r+1})$ when applied to a subinterval of length H, it follows that, under appropriate conditions (see, for example Stoer and Bulirsch 1980), the global error involved in using the basic method of ψ when the interval of integration is partitioned into subintervals of length H is $O(H^r)$. Thus the cost of using ψ with error tolerance $\varepsilon_{\mathrm{D}k}$ is proportional to $\varepsilon_{\mathrm{D}k}^{-1/r}$.

To follow the approach in Fritsch, Kahaner and Lyness (1981), it is assumed that each call to ψ is independent of every other one. In the simplest implementation, this would mean that ψ would always begin from the point a when obtaing a value of $\mathbf{g}(s)$ at an integration point. Since we have assumed that the use of inexact data by ϕ does not change the sequence of computational steps in ϕ, we shall also assume that the number of function evaluations required by ϕ is fixed at, say, N. If the same tolerance $\varepsilon_{\mathrm{D}k}$ is specified on each call to ψ, then the total work done will be proportional to $N\,\varepsilon_{\mathrm{D}k}^{1-/r}$ that is, proportional to $\varepsilon_{\mathrm{Q}k}^{-1/(d+1)}\,\varepsilon_{\mathrm{ODE}k}^{-1/r}$ Using (12) and the constraint $\varepsilon_k = \varepsilon_{\mathrm{Q}k} +$ $\varepsilon_{\mathrm{ODE}k}$, we minimize this expression obtaining

$$\varepsilon_{\mathrm{Q}k} = \frac{r}{d+r+1}\varepsilon_k, \qquad \varepsilon_{\mathrm{ODE}k} = \frac{d+1}{d+r+1}\varepsilon_k, \tag{13}$$

as the appropriate choices to minimize the total amount of work required for the computations done in the interval (s_{k-1}, s_k). Note that the specific values of the constants of proportionality will not affect $\varepsilon_{\mathrm{Q}k}$ and $\varepsilon_{\mathrm{ODE}k}$ as given in (13).

The choice of $\varepsilon_{\mathrm{Q}k}$ and $\varepsilon_{\mathrm{D}k}$ must also be such that the computation is stable. In particular, $\varepsilon_{\mathrm{D}k}$ must not be so large as to preclude the possibility of ϕ being able to converge given the tolerance $\varepsilon_{\mathrm{Q}k}$. Since ϕ is a linear process, assume it has a linear method for estimating the error of the computation in a given subinterval, let this process have condition number $\mathrm{C_E}$ when applied over a subinterval of unit length (see the discussion of $\mathrm{C_B}$ above). Thus, for a subinterval of length $s_k - s_{k-1}$, the bound on the error in the error estimation process of ϕ due to using inexact data from ψ is $\mathrm{C_E}(s_k - s_{k-1})\,\varepsilon_{\mathrm{D}k}$. Thus it follows from (12) that the inequality

$$\varepsilon_{\mathrm{Q}k} > \mathrm{C_E}(s_k - s_{k-1})\,\varepsilon_{\mathrm{D}k} = \mathrm{C_E}(s_k - s_{k-1})\frac{\varepsilon_{\mathrm{ODE}k}}{(s_k - s_{k-1})\,\mathrm{C_B}} = \frac{\mathrm{C_E}}{\mathrm{C_B}}\varepsilon_{\mathrm{ODE}k} \tag{14}$$

should be satisfied for all k to ensure stability of the AQR in all subintervals (s_{k-1}, s_k).

From (10), (12) and (13) it follows that

$$\varepsilon_{\mathrm{D}k} = \frac{(d+1)}{(r+d+1)}\,\frac{1}{\mathrm{C_B}(b-a)}\,\varepsilon_{\mathrm{T}}; \qquad \varepsilon_{\mathrm{Q}k} = \frac{r}{(r+d+1)}\,\frac{(s_k - s_{k-1})}{(b-a)}\,\varepsilon_{\mathrm{T}}. \tag{15}$$

Note that ε_{Dk} does not depend upon k. Combining (14) with (15) leads to the global stability requirement

$$r\, C_B > (d + 1)\, C_E. \tag{16}$$

Implementation

It was assumed in the previous section that each call to the ODES ψ was independent of all other calls to ψ. In the simplest implementation this would lead us to call ψ always taking a as the left endpoint of the interval of integration. Since we cannot tell in advance at which points the AQR will need a function value we cannot simply make one pass with ψ and obtain all the function values needed.

This now suggests the following more efficient two stage strategy. First, call ψ with a tolerance $\varepsilon_{Dk}/2$, and obtain the function values at the points s_k of the partition P_N. Second, in solving (2) in each subinterval (s_{k-1}, s_k), $k = 1, 2, ..., N$ when the AQR ϕ requires a function evaluation, ψ is called with left starting point s_{k-1}, the previously computed function value at s_{k-1} given, and a tolerance of $\varepsilon_{Dk}/2$. Since constants do not affect the analysis leading up to (13), ε_{Qk} and ε_{Dk} are still chosen according to (15), subject to (16) being satisfied. Assuming that the error propagated by ψ due to using an inexact starting value at s_{k-1} is damped by ψ (as is typically assumed when error control strategies of ODES depend upon local error estimation), we expect to obtain function values accurate to the required tolerance of ε_{Dk}.

A more efficient strategy might be to replace the second stage above with the use of an interpolating function of some sort (for example, cubic splines). However, this approach has two difficulties. It leads to a three tiered system for solving (2) (that is, the use of an ODES is followed by the use of an interpolation routine, which in turn is followed by the use of an AQR) in contrast to the two tiered method. Secondly, it appears that when one assigns appropriate tolerances for each of the three routines to be used, an attempt to choose them optimally to reduce computational costs is highly dependent on the particular problem being solved. Thus, while it may well be possible to tune such a styem to be efficient for particular problems, it seems that it is difficult to derive appropriate strategies for the choice of error tolerances in a more general setting. Consequently, we have not used this three tiered approach here.

Using hull curve offset data for a 38 foot developable hull sloop (Fig 2), the mapping algorithm together with criteria (13), (14) and (16) was successfully employed in the complete generation of each hull plate (Fig 3) with only very short CPU times being required on a CYBER 170-730 computer. The AQR used was QUANC8 (d = 8, Forsythe, Malcolm and Moler 1977) and the ODES used was RKF45 (r = 4, Forsythe, Malcolm and Moler 1977).

Precise results regarding the efficiency of the algorithm and the error bound strategies outlined in this work are currently under investigation using surface patches of regular circular cones for which simple analytic mapping formulas exist.

References

Clements, J.C. 1981. A computer system to derive developable hull surfaces and tables of offsets, Marine Technology, 18: 227-233.

Clements, J.C. and **Leon, L.J.** 1986. A fast, accurate algorithm for the isometric mapping of a developable surface, in press.

Clements, J.C. 1984. Developed plate expansion using geodesics, *Marine technology,* 21: 384-388.

Dahlquist, G. and **Bjorck, A.** 1969. *Numerical Methods,* Prentice-Hall.

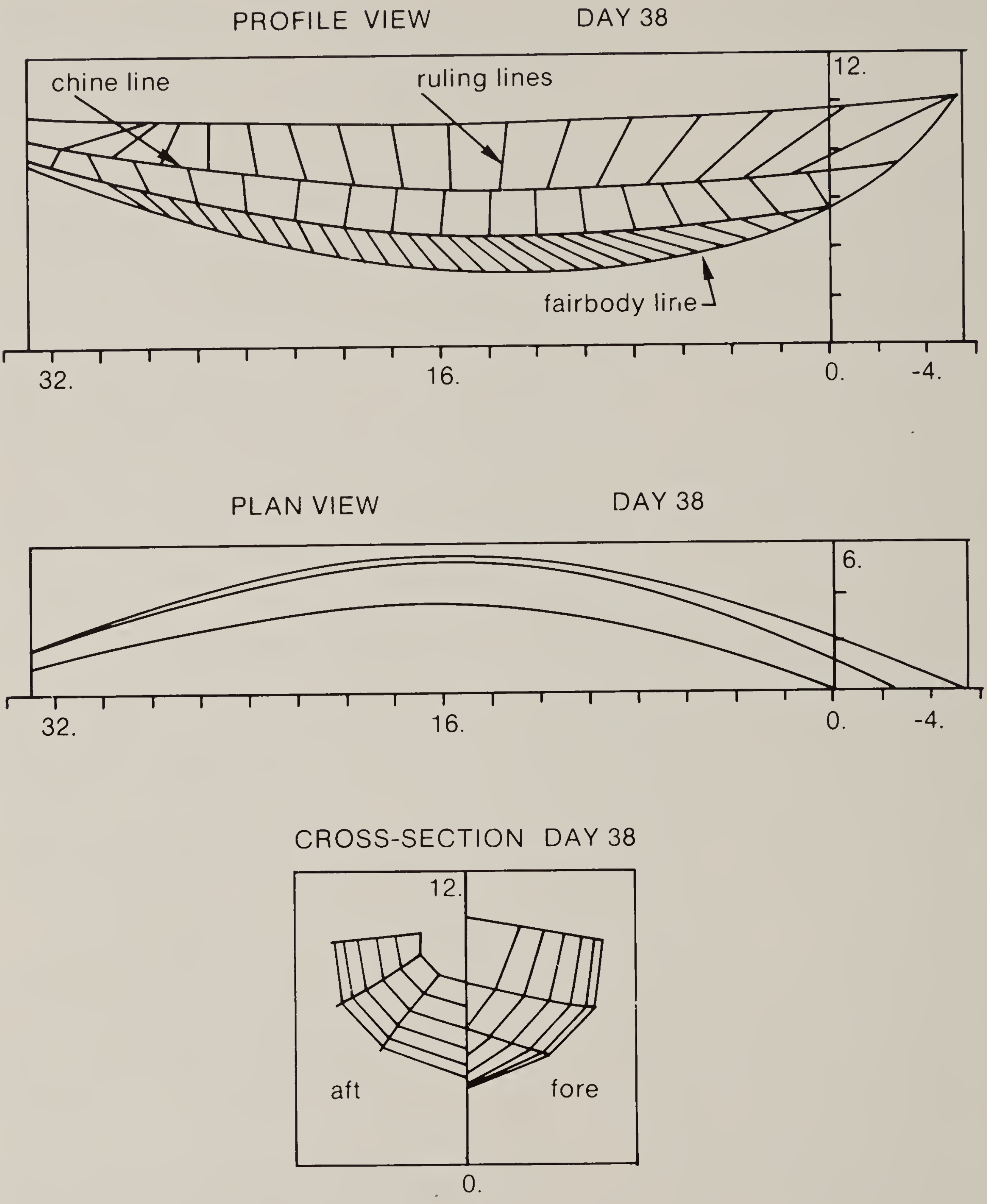

Fig 2 The profile, plan and cross-section views of a 11.583 m developable hull sloop DAY38. The profile view shows the ruling lines computed for each of the three developable surfaces which comprise one side of the hull form. All units are in 0.3048 m.

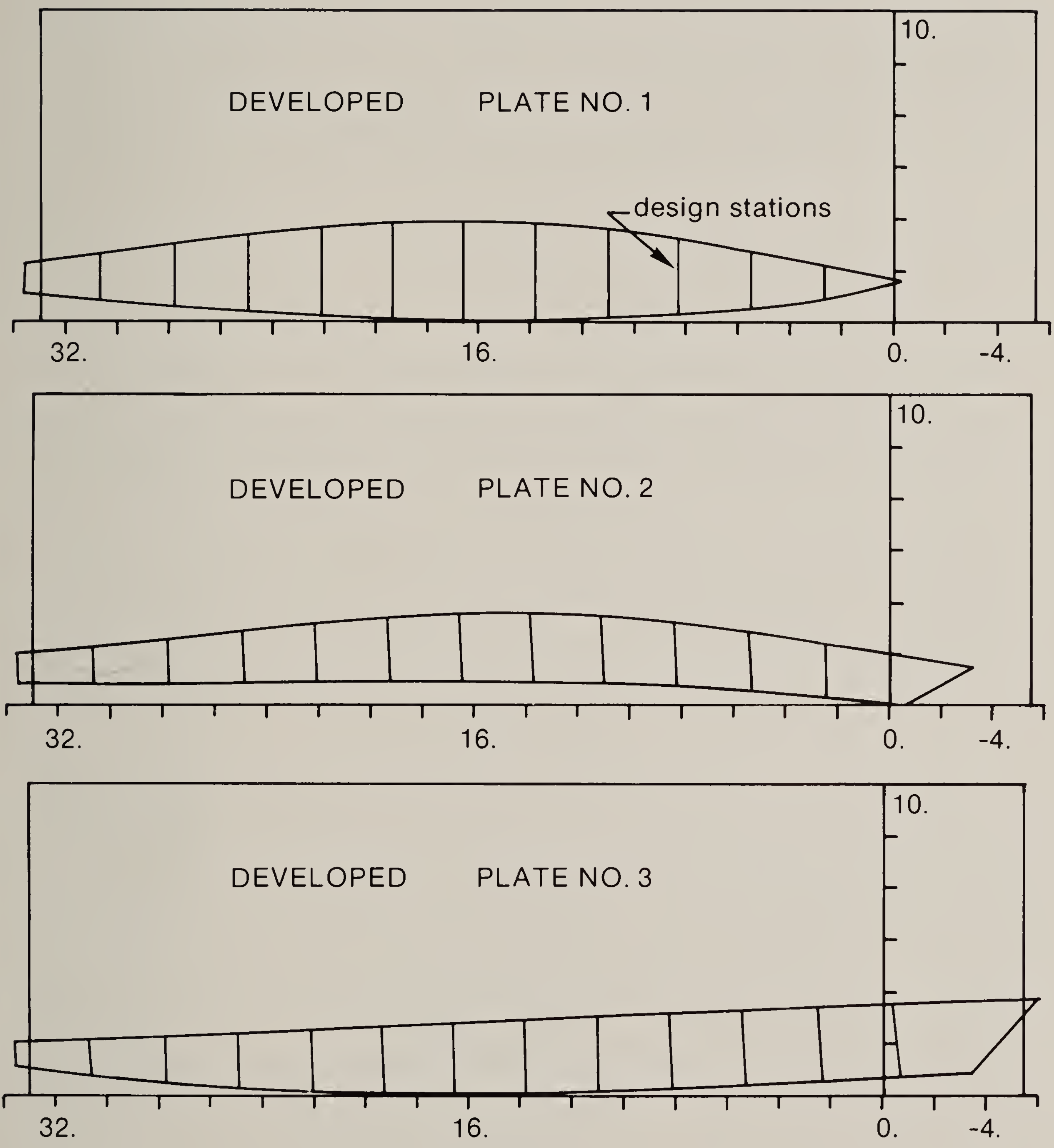

Fig 3 The results obtained for the mapping or "plate expansion" of each of the 3 developable hull surfaces of DAY38. Plate No. 1 corresponds to the surface adjacent to the keel; plate No. 2 to the next surface up and plate No. 3 to the uppermost surface.

Fritsch, F.N., **Kahaner, D.K.** and **Lyness, J.N.** 1981. Double integration using one-dimensional adaptive quadrature routines: A software interface problem, *ACM T.O.M.S.*, 7: 46-75.

Forsythe, G.E., **Malcolm, M.A.** and **Moler, C.B.** 1977. *Computer Methods for Mathematical Computations*, Prentice-Hall.

Kreyszig, E. 1959. *Differential Geometry*, University of Toronto Press.

Stoer, J. and **Bulirsch, R.** 1980. *Introduction to Numerical Analysis*, trans. R. Bartels, W. Gautschi, & C. Witzgall, Springer-Verlag, New York.

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THE APPENDAGES OF LOPHOURA TETRAPHYLLA HO, 1985 (COPEPODA: SPHYRIIDAE) A PARASITE OF ANTIMORA ROSTRATA IN DEEP WATERS OF THE NORTHWEST ATLANTIC OCEAN

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The detailed structure of the cephalothoracic appendages of *Lophoura tetraphylla*, a parasitic copepod of *Antimora rostrata*, are described. The first and second antennae possess a structure similar to that reported for other genera in the family Sphyriidae. The morphology of the mandible of *L. tetraphylla* is discussed in relation to other previous descriptions of this appendage. *Lophoura tetraphylla*, like other members of the family, is shown to exhibit extensive regressive metamorphosis of the appendages during the mesoparasitic stage of its life cycle.

Les structures détaillées des appendices céphalothoracique de *Lophoura tetraphylla*, un copépode parasite d'*Antimora rostrata*, sont décrites. Les structures des premières et deuxièmes antennes sont similaires a celles rapportées pour d'autres genres de la famille Sphyriidae. La morphologie de la mâchoire inférieure est discutée par rapport aux descriptions antérieures de cet appendice. *Lophoura tetraphylla*, comme d'autres membres de cette famille, montre la métamorphose régressive des appendices pendant la stade mésoparasitique de son cycle vital.

Introduction

The structure of the appendages of adult female sphyriid copepods are, virtually unknown. Wilson (1919) described the structure of some of these appendages for 6 genera (*Opimia, Paeon, Perplexis, Lophoura, Sphyrion* and *Trypaphylus*). Kabata (1979) in his review of the family Sphyriidae Wilson, 1919 gave detailed descriptions of the appendages for *Sphyrion lumpi* (Kroyer, 1845) a parasite of *Sebastes* sp. in the North Atlantic. *Sphyrion lumpi* possesses appendages which may be considered typical of the family. The first and second antennae and first and second maxillae are reduced to sub-spherical swellings with remnants of apical armature in the form of short setae (first maxillae exempt of apical armature). The maxillipeds, swimming legs and occasionally, the second maxillae, are sometimes lost after metamorphosis in some genera (Kabata 1979). As far as is known, only four species, *Paeonocanthus antarcticensis* Hewitt, (1965), a parasite of *Bathylagus* sp. in the North and South Atlantic, *Paeon ferox* Wilson, (1919) and *P. versicolor* Wilson, (1919) from the gill cavities of charcharhinid sharks and, *S. lumpi* retain complex appendages (maxillipeds) after metamorphosis during the mesoparasitic stage of their lives (Hogans, 1986; Wilson, 1919; Kabata, 1979).

To examine the extent of reduction of the appendages in the post-metamorphosis female sphyriid I have examined several species recovered from hosts collected in Canadian Atlantic waters. The appendages of *Lophoura gracilis* Wilson, (1919) are described in a separate paper (Hogans and Dadswell 1985). Another species which I have found, *Lophoura tetraphylla*, is a parasite of the flesh of the blue hake (*Antimora rostrata*). It was recently described by Ho (1985) from two specimens collected in deep waters of the continental slope of the Northwest Atlantic. Due to a scarcity of material, Ho was unable to describe the appendages of this parasite in detail. Herein, the appendages of two adult female *L. tetraphylla* are described.

Materials and Methods

The two specimens of *L. tetraphylla* were recovered from the somatic musculature of *A. rostrata* collected during a cruise of the R/V Gyre, Texas A&M University), in the Carson Canyon area near the eastern edge of the Grand Banks of Newfoundland. Depth of capture was 1700 m. The copepods were dissected from the fish at sea and fixed and stored in 70% ethanol. The cephalothorax of each specimen was cleared in 85% lactic acid. Figures were drawn with the aid of a camera lucida.

Lophoura tetraphylla Ho, 1985 (Fig. 1)

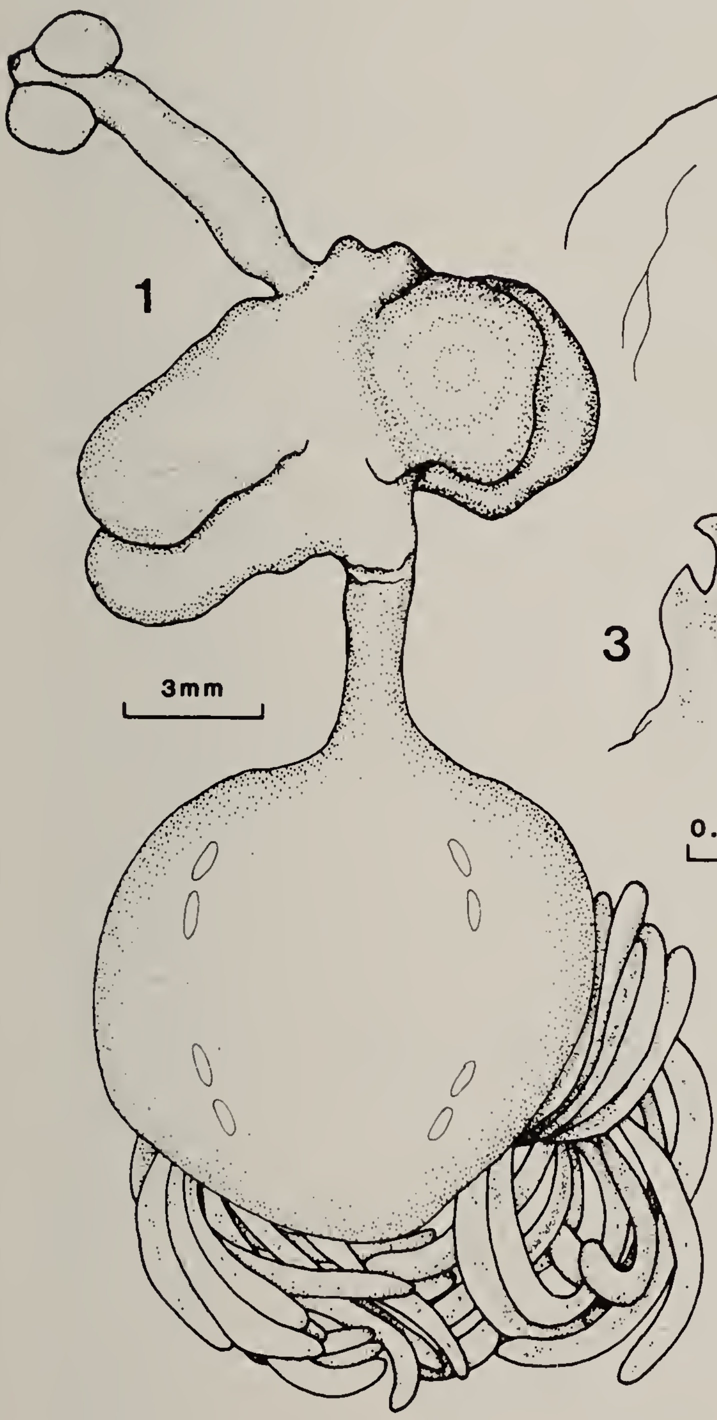
General appearance: *Lophoura tetraphylla* is a typical sphyriid copepod having a complex holdfast, several clavate uropods (branching or single, depending upon the genus and often referred to as respiritory cylinders) and a large, robust genital segment. In general appearance the specimens collected for this study did not differ significantly from those described by Ho (1985) who gave the distinguishing feature of the species as a holdfast as large as or larger than the trunk. The smallest of the two specimens recovered possessed a holdfast about three-quarters the size of the trunk. Holdfast structure (four, large spherical processes) not size, is probably the best distinguishing character for the species. The shape of the cephalothorax (cylindrical with two lateral pad-like processes), holdfast, neck, trunk, uropods and perianal elevation of the four known specimens of *L. tetraphylla* are similar.

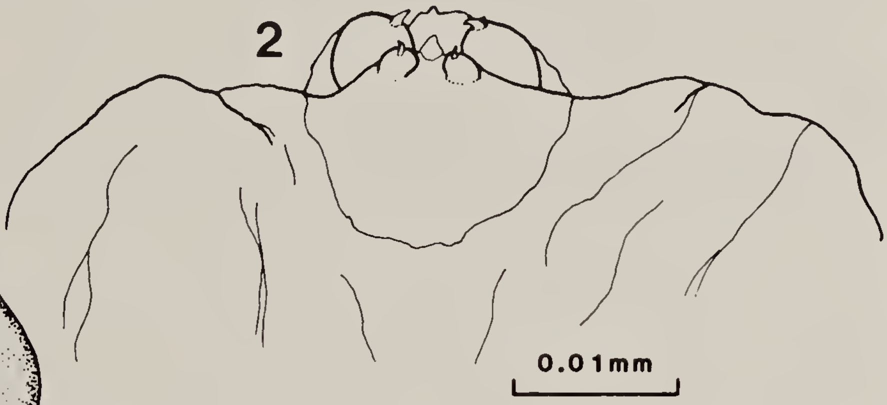
The appendages: The first and second antennae of *L. tetraphylla* (Fig. 2) are located near the anterior extremity of the cephalothorax on the dorsal surface. Each is sub-spherical and armed at the apex with a single seta. The second antenna is approximately three times the size of the first and located slightly anterior to it. Their structure is similar to that reported for *S. lumpi*, although this species possesses a second antennae with two apical setae (Kabata 1979).

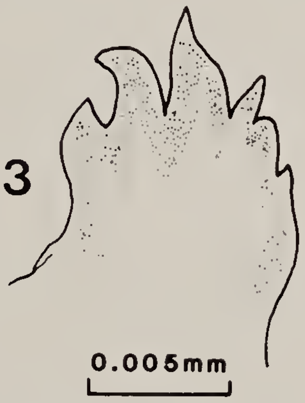
The mouth of *L. tetraphylla* is siphonostome and located near the end of the cephlothorax on the ventral surface. When the cephalothorax is cleared, the mandibles (Fig. 3) can be seen to lie on each side and slightly within the mouth tube. Each mandible is armed with 6 teeth of various sizes, the largest being medial in position. The mandible structure is unlike that reported for other sphyriids (no species identified) by Wilson (1919): stylet-shaped with adjacent surfaces set with a row of five teeth. Wilson's is apparently the only description (no figures were included) of the mandible of a female sphyriid copepod other than that of *L. tetraphylla*. It is likely that Wilson (1919) did not correctly interpret the structure of the mandible in his paper.

Slightly below and on each side at the mouth tube are either the first or second maxillae. Their position would indicate they are the first maxilla as the second are often found more posterior to the mouth in *S. lumpi* (Kabata, 1979) and *L. gracilis* (Hogans and Dadswell, 1985). The structure of these appendages, subspherical and armed apically with two short setae, however is similar to that reported for the second maxilla of *S. lumpi*. If these appendages are first maxillae, then the second are lost in *L. tetraphylla*. Since the first maxilla of both *S. lumpi* and *L. gracilis* lack apical armature, I suggest that *L. tetraphylla* possesses indiscernable first maxillae, and second maxillae in a position more anterior than is usual for the family. A careful examination of both specimens collected for this study shows a complete lack of both maxilliped and swimming legs; a typical feature for the majority of genera within the family Sphyriidae.

Mesoparasitic families of copepods, such as the Lernaeidae, and Pennellidae, do not undergo regressive metamorphosis (Kabata pers. comm.). It is assumed that the structure of the appendages remain fairly constant from initial attachment to the host to the maturation of the females. In Pennellidae for example, the appendages remain structurally as extensive as they were in the copepodid stage, but are dwarfed by the excessive growth of the cephalothorax and holdfasts (see Kabata 1979). This can be seen in the Lernaeidae, as well; members of this family also retain complex appendages which are extremely small in proportion to the total size of the parasite. Since the premetamorphosis stages of the female sphyriid copepod (except for the early metanauplius of *S. lumpi*) are unknown, it can only be assumed from the available information on the adults that the appendages of the female sphyriid are relatively simple and change significantly during its life-history, undergoing extensive regressive metamorphosis. The site of attachment of *L. tetraphylla* on its host is apparently specific; all four known specimens being recovered from the somatic musculature. This is a feature shared with some other genera (*Lophoura, Opimia, Paeon*) in the family (Wilson, 1919).







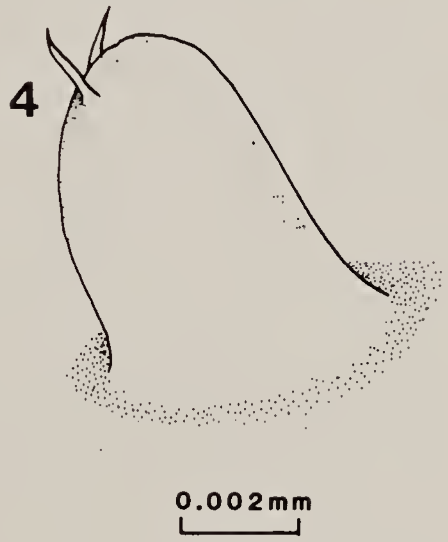


Fig 1 *Lophoura tetraphylla* Ho, 1985, dorsal.

Fig 2 Anterior extremity of cephalothorax, dorsal.

Fig 3 Mandible, ventral.

Fig 4 Second maxilla (?), ventral.

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References

Ho, J.S. 1985. Copepod parasites of deep-sea benthic fishes from the western north Atlantic. *Parasitology.* 90:485-497.

Hogans, W.E. and **M.J. Dadswell.** 1985. Redescription of *Lophoura gracilis* Wilson, 1919 (Copepoda: Sphyriidae) from *Synaphobranchus kaupi* in the Northwest Atlantic Ocean. *Can. J. Zool. 63:2940-2944.*

Hogans, W.E. 1986. *Paeonocanthus antarcticensis* (Copepoda: Sphyriidae) parasitic on the bathypelagic fish *Bathylagus euryops* in the Northwest Atlantic Ocean. *Sarsia.* 71: 305-308.

Kabata, Z. 1979. *Parasitic Copepoda of British Fishes.* The Ray Society, London, 463 p.

Wilson, C.B. 1919. North American parasitic copepods belonging to the new family Sphyriidae. *Proc. U.S. Natl. Mus.* 55(2296):594-604.

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PANNARIA LURIDA **IN ATLANTIC CANADA***

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The cyanophilic lichen *Pannaria lurida* has been collected from seventeen localities in southern Nova Scotia and two in southern New Brunswick. Previous reports of this lichen from Quebec are based on ill-identified or doubtful materials.

Le lichen cyanophilique *Pannaria lurida* a été ramassé de dix-sept localités dans le sud de la Nouvelle Ecosse et de deux localités dans le sud du Nouveau Brunswick. Des rapports antérieures de ce lichen provenant du Québec sont fondés sur des échantillons mal-identifiés ou d'origine douteuse.

Apart from several unconfirmed reports of *Pannaria lurida* (Mont.) Nyl. in Quebec (Lepage, 1947, 1958; to be discussed below) and a very doubtful one from Newfoundland or Labrador (Eckfeldt 1895, as *Physma luridum* Mont.), nothing is known about the occurrence of this interesting but often overlooked species in Canada. *Pannaria lurida* belongs to the *P. rubiginosa* group (Jørgensen 1978) and is distinguished from the most closely related species, *P. rubiginosa* (Ach.) Bory, by its larger, conspicuously wrinkled and often greyish green thallus lobes (Fig 1A & B). The more greyish coloration is caused by the pronounced accumulation of pannarin, a chlorinated depsidone which is produced in lesser amounts in *P. rubiginosa* and its sorediate counterpart *P. conoplea* (Ach.) Bory. The algal symbiont is *Nostoc* as is usual with members of Pannariaceae.

Specimens in the Smithsonian Institution (US) and the Farlow Herbarium (FH) indicate that *P. lurida* had been collected at least as far north as Maine (South Thomaston and Warren in Knox County and Salisbury Cove in Hancock County). The species seems to be restricted to the eastern seaboard of northern North America, the southeastern U.S.A. (Hale 1979) and some mountains in the Caribbean, although some misidentified specimens of *Pannaria* from the Hawaiian Islands have been seen under this name (GB, Göteborg). During our surveys of forest lichens in eastern Canada and the adjacent parts of Maine we have noted the presence of *P. lurida* in southern Nova Scotia and less frequently along the Northumberland Straits and in eastern Maine (Fig 2). These areas are more or less strongly influenced by an oceanic climate and lie outside or along the edge of the boreal coniferous zone. The habitats are mostly very wet mixed forests in which *Fraxinus americana* L., *F. nigra* Marsh. and *Acer rubrum* L. are dominant. *Pannaria lurida* is a rare member of the Lobarion. It often grows together with related species of *Pannaria*, most often *P. rubiginosa* and *P. conoplea* but also *P. ahlneri* P. M. Jørg. and *P. leucosticta* (Tuck. in Darl.) Nyl. (in southern Nova Scotia). By contrast to these species, all of which are able to grow on coniferous bark, especially on that of *Thuja*, *P. lurida* has been found only on deciduous trees. We have seen the lichen on the following phorophytes (number of observations in parentheses): *Acer rubrum* (8), *A. saccharum* Marsh. (1), *Fagus grandifolia* Ehrh. (1), *Fraxinus americana* (5), *F. nigra* (1), *Malus pumila* Mill. (1),

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* NRCC No. 26726

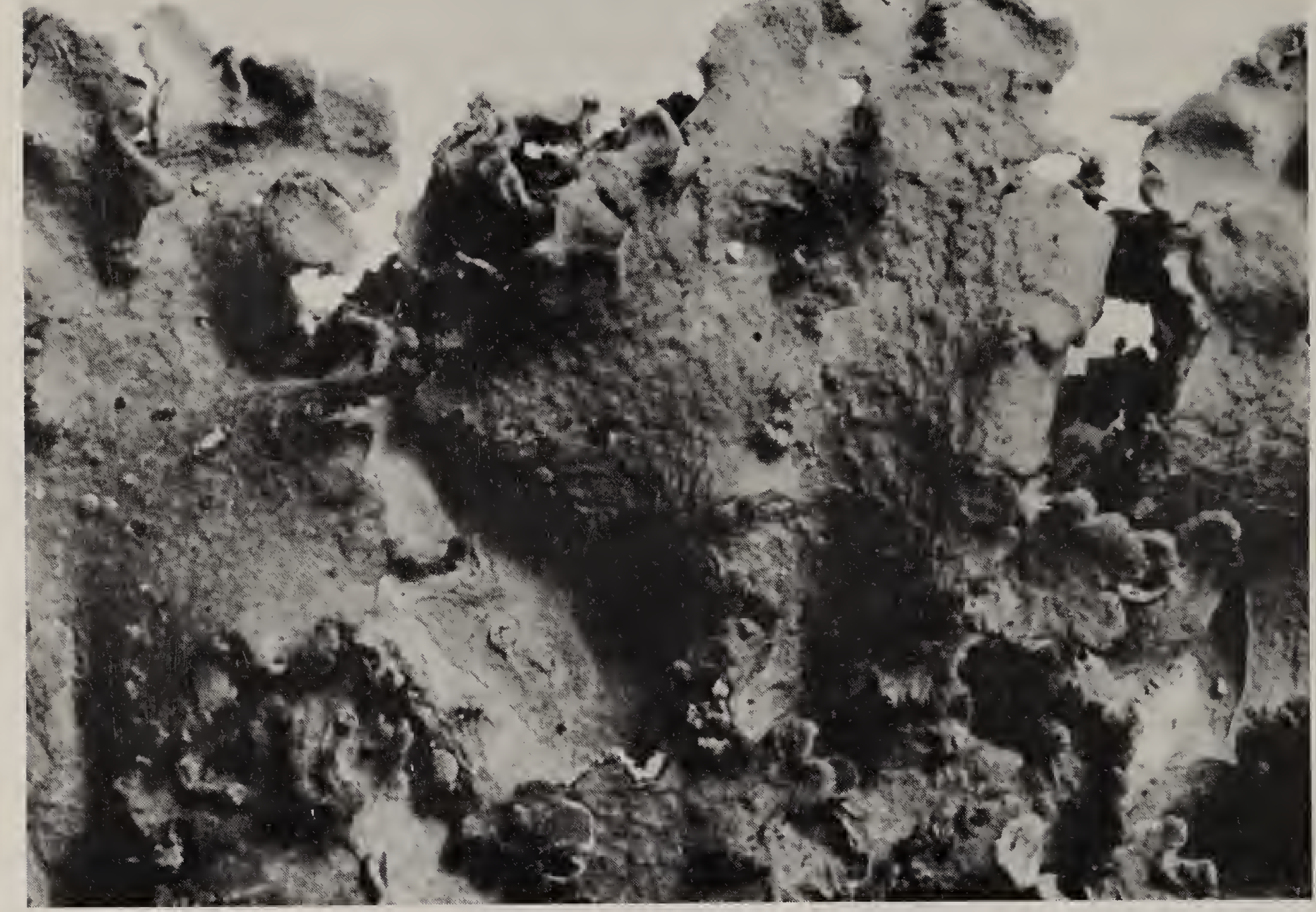

Fig 1A *Pannaria lurida*. Marginal lobes of thallus in air dried condition, showing the characteristic wrinkles which are caused by an inhomogeneous algal layer (Jørgensen 1978). x6.

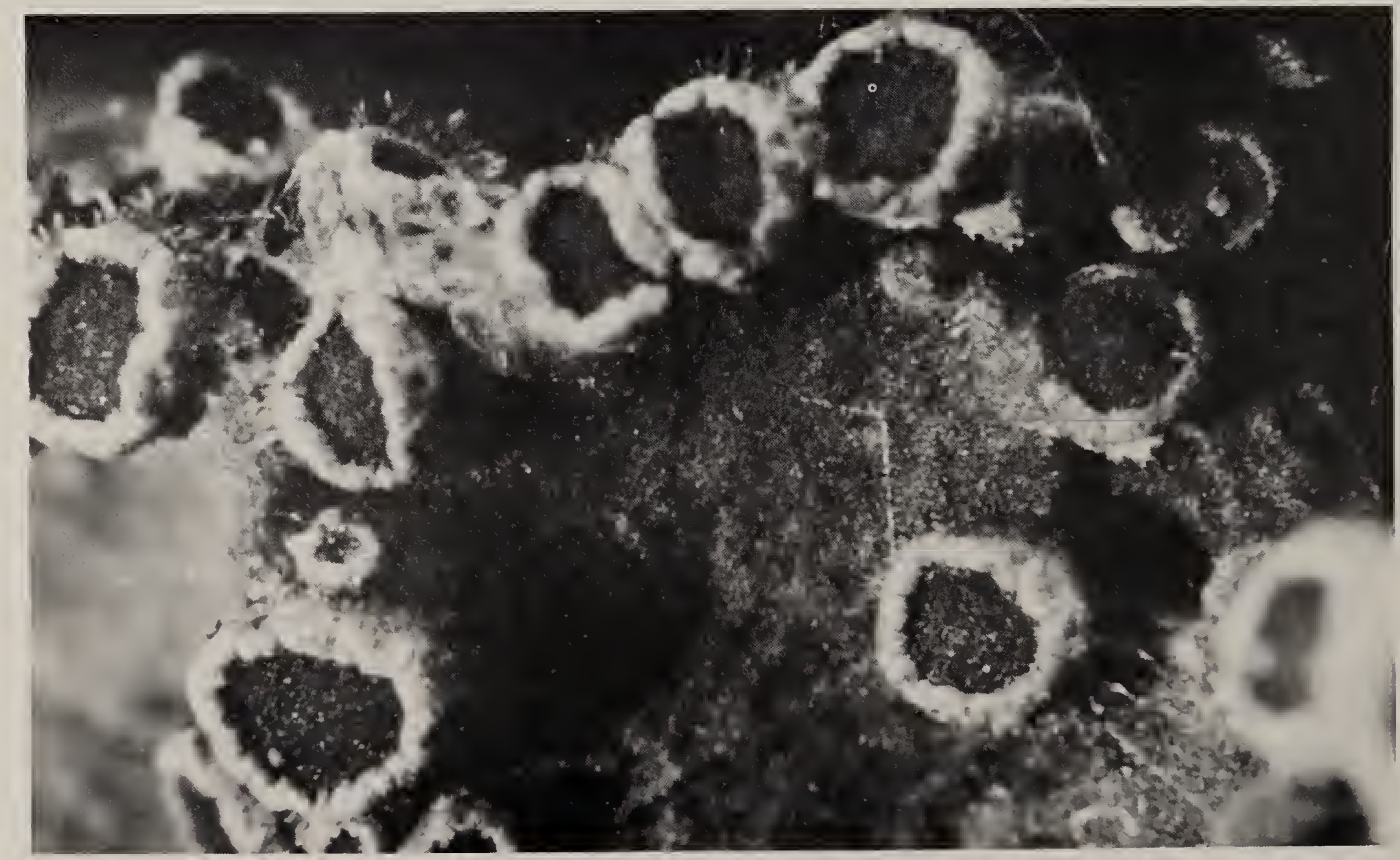

Fig 1B *Pannaria lurida*. Partial view of thallus with apothecia, hydrated for 30 min. The wrinkles are still in evidence. x15.

Populus tremuloides Michx. (2), *P. balsamifera* L. (1) and *Quercus ruba* L. (1). Additional phorophytes from Maine include *Salix* spp. (3), *Sorbus americana* Marsh. (1) and *Ulmus* sp. (1). On some trees in southern Nova Scotia (*Acer* and *Malus*), *P. lurida* was seen in great abundance, sometimes covering the trunk face up to a height of 3 m.

The distribution of *P. lurida* is predominantly of an Appalachian type. Together with *Anzia colpodes* (Ach.) Stizb., *Cetraria aurescens* Tuck., *Normandina pulchella* (Borr.) Nyl., *Pannaria leucosticta*, *Parmotrema perlatum* (Huds.) Choisy and, on *Fagus*, *Trypethelium virens* Tuck. in Darl. (Brodo 1968), *P. lurida* belongs to a distinct group of Appalachian elements which has become established in the interior of mainland Nova Scotia and shows no particular preference for coastal habitats. None of these lichens are found in Newfoundland but all of them occur sporadically in eastern New Brunswick (Kent and/or Northumberland Counties) and/or on the Gaspe Peninsula or further up in the valley of the St. Lawrence River (Lepage 1949, 1958; Brodo and Gowan 1982). At least several additional lichens with an Appalachian type of distribution are known to have isolated populations in the interior of Nova Scotia but are unknown from the Northumberland Straits area of eastern New Brunswick or from Quebec. To this group belong *Hypotrachyna imbricatula* (Zahlbr.) Hale, *Parmotrema mellissii* Vain., *Thelotrema subtile* Tuck., *Heterodermia squamulosa* (Degel.) W. Culb. and *Ochrolechia yasudae* Vain. (Maass, unpublished data).

Revisions of lichen specimens from the Herbarium of Lepage (in Herbier Louis-Marie, QFA, Quebec) previously identified as *P. lurida* revealed that this species is not

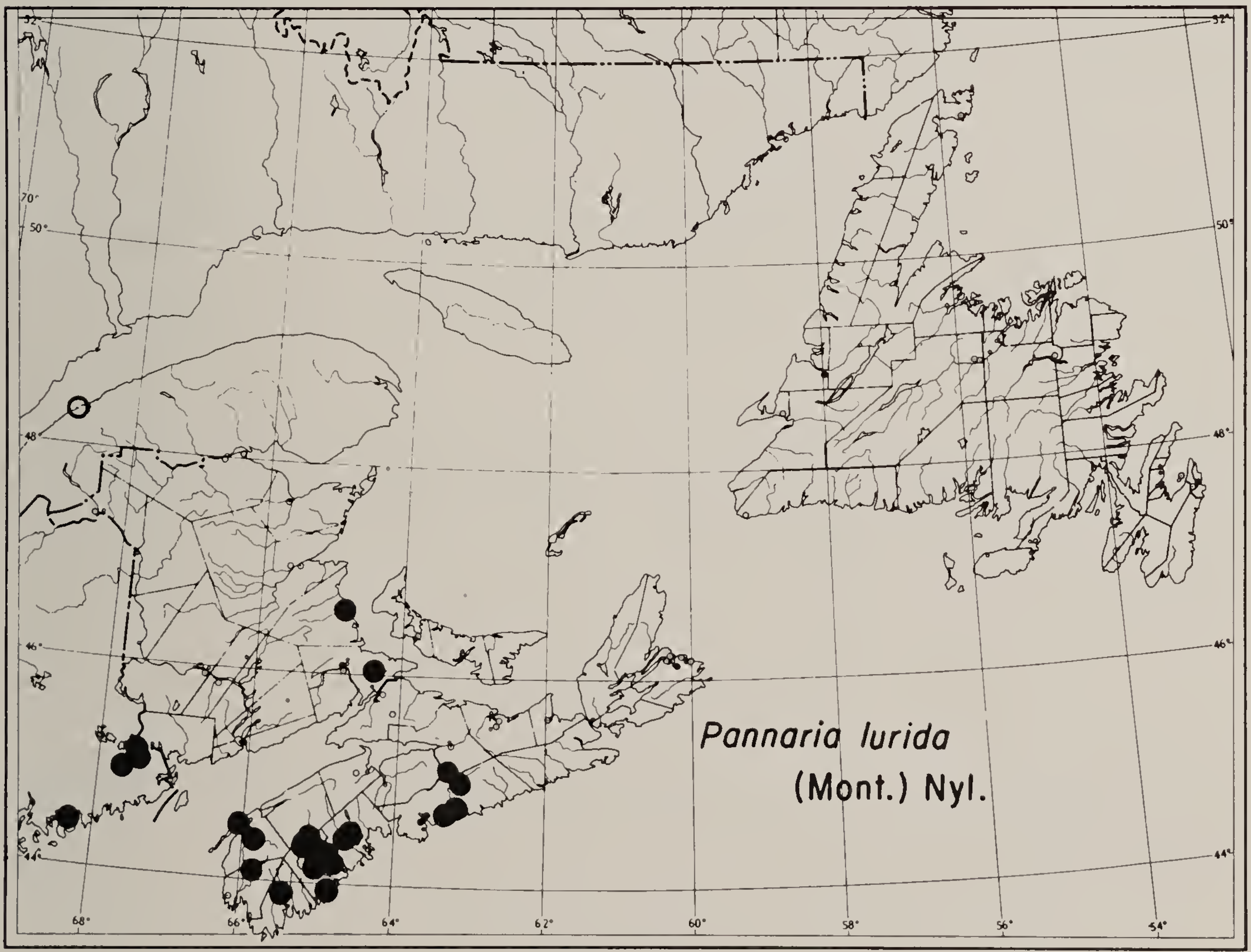

Fig 2 Distribution of *Pannaria lurida* in Atlantic Canada and the adjacent parts of Maine. The open circle refers to an unconfirmed and dubious report by Lepage (1958) as discussed in the text.

presently known from Quebec with any degree of certainty and should be struck from the checklists of that province. Specimens reported as *P. lurida* from Waterloo (Lepage 1949) and Ile Lemoine in James Bay (Lepage 1958) have been revised as *Lecanora cinereofusca* H. Magn. and *Pannaria rubiginosa* (Ach.) Bory respectively. Similarly, the *Pannaria* from calcareous rocks of the Rimouski R. Valley (# 4169 in Lepage 1949) turned out to be *P. leucophaea* (Vahl.) P. M. Jørg. The only specimen not seen was collected by LeGallo on rocks at Cap à l'Original, 48°22'N and 68°49'W (Lepage 1958). It is possibly at the Missouri Botanical Gardens (MO) or in Herb. Dodge (Burlington, Vt.) and was originally listed under the name *P. russellii* Tuck. (LeGallo 1954). It is highly unlikely that it represents *P. lurida*.

Specimens studied: Except as otherwise indicated the collections were made by the authors and are in their Herbarium.

NOVA SCOTIA

Colchester Co.: St. Andrews R. ca. 3 km W of Lanesville, 86J-1a.

Halifax Co.: Murchyville, about 1 km northwest from bridge over Little R., 82K-3a, c; Musquodoboit Harbour, between Petpeswick L. and Scots L., 82E-23a; and Porters Lake, along Hwy. 107 north of Grand L., 82E-22b.

Lunenburg Co.: New Cornwall, in floodplain of brook between Caribou L. and Little Mushamush L., 81D-90a; and West Northfield, on route 10 about 10 km northwest of Bridgewater, Brodo and Argus # 18955 (CANL).

Queens Co.: Kempt, 2.5 km on road to New Albany, 82D-39e; Kejimkujik National Park, on road from Fish Hatchery to George Bay, 0.5 and 2.5 km south from turnoff to McGinty L., 81K-4g, 81K-5c; between Hibernia and Caledonia near road to Maugher, 82I-4b; between north end of Ponhook L. and route 8, 82I-3b; between Greenfield and Buckfield in burnt-over swampy woodland, 82D-25a; between Bangs Falls and Riversdale, along Medway R. near Burnaby Bk., 82D-21a; Indian Gardens on logging road west of Mersey R., 1 km from gate, 82E-41e, g; and Summerville, in swampy woods south of Hwy. 103, 81E-30e.

Shelburne Co.: Ohio Road 12.8 km north from Hwy. 103, 83K-30a, b.

Yarmouth Co.: North Kemptville, near steel bridge over Tusket R. on road to Titus Ridge, 83A-30b.

Digby Co.: Sissiboo R. at Devils, 82D-14h; and Lake Medway, 82D-46r.

NEW BRUNSWICK

Westmorland Co.: Aboujagane Road 20 km north of Sackville, moist *Abies - Picea - Acer rubrum* moss herb forest near edge of *Alnus rugosa* swamp, Harries and Maass # 79H-1a, # 79065 in Herb. Harries.

Kent Co.: Headlands of Chockpish R., near Hwy. 11, 6 km south from Hwy. 134 jct. in Rexton, 83G-23c.

Acknowledgements

The authors are grateful to Dr. Robert Gauthier of Laval University for his generous help in making available or locating the specimens cited in the checklists of Quebec lichens by Lepage.

References

Brodo, I.M. 1968. *The lichens of Long Island, New York: A vegetational and floristic analysis.* The University of the State of New York. Albany, N.Y.

Brodo, I.M. and **Gowan, S.** 1983. Un apercu de la répartition des lichens de l'est de l'Amérique du Nord. *Bull. de la Soc. Bot. du Quebec* 5: 13-30.

Eckfeldt. 1895. An enumeration of the lichens of Newfoundland and Labrador. *Bull. Torr. Bot. Club* 22: 239-260.

Jørgensen, P.M. 1978. The lichen family Pannariaceae in Europe. *Opera Botanica* 45.

LeGallo, C. 1954. Lichens récoltés dans le Québec (Canada). *Rev. Bryol. Lichenol.* 23: 317-325.

Lepage, E. 1947. Les lichens, les mousses et les hépatiques du Québec. *Le Naturaliste Canadien* 74: 225-240.

Lepage, E. 1949. Les lichens, les mousses et les hépatiques du Québec. *Le naturaliste Canadien* 76: 45-88.

Lepage, E. 1958. Premiere supplément au catalogue des Lichens du Québec. *Le Naturaliste Canadien* 85: 169-198.

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Volume 36, pp. 137-144

THE CONCEPT OF THE PERILIMNION

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Seasonal variations in surface and ground water supply and increasing attention to ionic and mass balances in aquatic eco-systems require more specific definitions of hydrologic parameters to recognize sources and sinks for biologically significant geochemistry. The term "Perilimnion" is proposed to define that zone of the catchment in which groundwater developed by surface runoff and percolation may enter (or leave) the limnic environment. The perilimnion, therefore, is an aquifer, whose geochemistry may affect, or be affected by, the waters of a lake. The term "Tardelimnion" is proposed to define that portion of the limnic environment in which deposition of limnogenic sediments (autochthonous or allochthonous) contribute to an aquitard, whose low coefficient of hydraulic permeability ($<10^{-6}$ cm s^{-1}) virtually precludes significant hydrologic or geochemical interaction between lake and ground waters.

Les variations saisonnières dans la disponibilité des eaux de surface et des eaux souterraines et l'attention accrue maintenant accordée aux balances de masse et d'ions dans les écosystèmes aquatiques nécessitent les définitions plus precises des paramètres hydrologiques pour mieux identifier les sources et les sources negatives de la géochimie d'intérêt biologique. Le terme "perilimnion" est proposé pour le zone de captage d'eau dans lequel les eaux developpé par l'écoulement des eaux de surface et les eaux de filtration peuvent entrer ou sortir de l'environnement limnique. Le perilimnion est donc un aquifère qui peut influencer ou etre influencé par les eaux d'un lac. Le terme "tardélimnion" est proposé pour définir la portion de l'environnement limnique dans lequel le dépôt de sédiment limnogénique (autochthone ou allochthone) contribue à un aquitard dont le coéfficient de perméabilité hydraulique bas (10^{-6} cm s^{-1}) empêche des interactions significatives hydrologiques ou géochimique entre les eaux de lac et les eaux souterraines.

Introduction

The responsibility for introducing additional terminology to an already linquistically rich limnological vocabulary is indeed formidable. Increasing recognition that a lake is not a "microcosm" (sensu Forbes, 1887), however, justifies attempts to improve precision.

Although van Helmont's (1748) experiments on a potted willow tree may possibly qualify him as the father of quantitative biogeochemistry, it was the Canadian limnologist D.S. Rawson (1939) who initially emphasized the role of basin morphology, hydrology, and geology on the biological development of lakes. The seminal trophic level studies of Lindeman (1942), and elaboration by Odum (1957) and others focussed increasing attention on the watershed as the biogeochemical 'forcing function' of fresh water ecosystems. Vollenweider (1968), and Deevey, (1970) distinguish between lithologic, hydrologic, and atmospheric sources and sinks for lake nutrients. Detailed and painstaking studies in the Hubbard Brook system (Likens, *et al*, 1977) have demonstrated that interrelations with the terrestrial part of the watershed have important downstream geochemical consequences. Case (1978), using conductivity and geochemical profiles, showed that up to 100% of flow in the Gay's River, Nova Scotia, system was derived from ground water during seasonal periods of low flow.

Ground water hydrologists have long maintained an interest in lake/ground water interactions. Winter (1976) summarizes four schools of thought common among hydrologists and lake water managers:

a) All lakes are discharge points of the ground water system and therefore do not lose water through their beds;

b) All lakes are points of recharge to the ground water system;

c) Ground water discharge occurs on one side of a lake and recharge occurs from the other side; or,

d) All of the above (see Born, *et al*, 1974, for review).

While it is not the purpose of this paper to venture into a hydrological debate, it is obvious from a limnological perspective that lake water/ground water interactions vary greatly between glaciated and unglaciated regions; the humid east and the arid west; the seasonal temperate region, and the thermally stable but hydrologically variable sub-tropic and tropic regions. Opinion (d) seems safest, if unsatisfactorily vague.

It is proposed here, however, that there are two related, but independent regions of lake water/ground water interaction, which are physically recognizable, and spatially definable.

The Perilimnion and the Tardelimnion

Numerical simulation models of the interaction of lakes and ground water (Winter, 1976), and ground water flow models over resistive and "leaky" beds (e.g., Vandenberg, 1982) demonstrate that, depending upon vertical and horizontal coefficients of permeability, some of the ground water originating within the watershed boundary may pass beneath the bed of lacustrine systems, therefore having no effect on the geochemistry of the overlying lake. Similarly, there is a zone at some distance upslope (and up-gradient) from the shoreline and surrounding a lake where percolating ground water, (including some fraction of surficial runoff and interstitial water from the watershed perimeter), may enter or leave the littoral zone, and is therefore an aquifer. I propose that this active zone should be formalized as the *Perilimnion* (Fig. 1), i.e., that portion of the catchment in which groundwater may enter or leave the limnic environment.

During periods of recharge and high runoff, it is probable that the perilimnion is a temporary source of ground water as a result of hydraulic head developed by more rapid rise of the lake surface level relative to the belated response of percolating ground water.

In most natural lakes fine-grained sediments of the central basin extend shoreward to the lower limit of the wave zone, and constitute an aquitard, with horizontal and vertical permeability coefficients $<10^{-6}$ cm s^{-1}. This zone, which consists of both allochthonous and autochthonous organic and inorganic particles, is underlain by even more impermeable silts and clays throughout glaciated regions. Frequently, glacier meltwater lakes are in clay-rich till, and moving ground water is restricted to the upper leached soil horizons. I propose that this zone of confined, or restricted ground water movement through lake sediments be formalized as the *Tardelimnion.*

In Sallie Lake, Minnesota, seepage accounted for 14% of annual inflow. McBride and Pfannkuch (1975) reported that 99% of ground water seepage into the lake occurred within 120 m of shore (<1/10 the distance to the center of the lake), in <2.0 m of water. They noted that fine-grained sediments (viz., the tardelimnion) in the central basin began about 300m from the shoreline.

Observations in Nova Scotian lakes indicate that gyttja underlain by silty clay occurs below about 3 m water depth (Yuill and Ogden, 1982). Shallow ground water wells, extending into bedrock beneath lake sediment (gyttja, silty clay, till) shows the presence of an hydraulic head against the lake bottom compared with shoreline piezometers in Second Chain Lake. Close interval thermal profiling with an armored Whitney thermal probe failed to indicate any ground water intrusion despite a steep thermal gradient between lake water (22.0 ± 0.2°C) and ground water (8.0 ± 0.5°C).

Similarly, at Kilkenny Lake, Nova Scotia, Ogden and Gillis, (1982) found that only ground water within *ca* 100 m of the lake shore entered the lake intermittently, and was quantitatively insignificant. Using ground water flow models developed by Van-

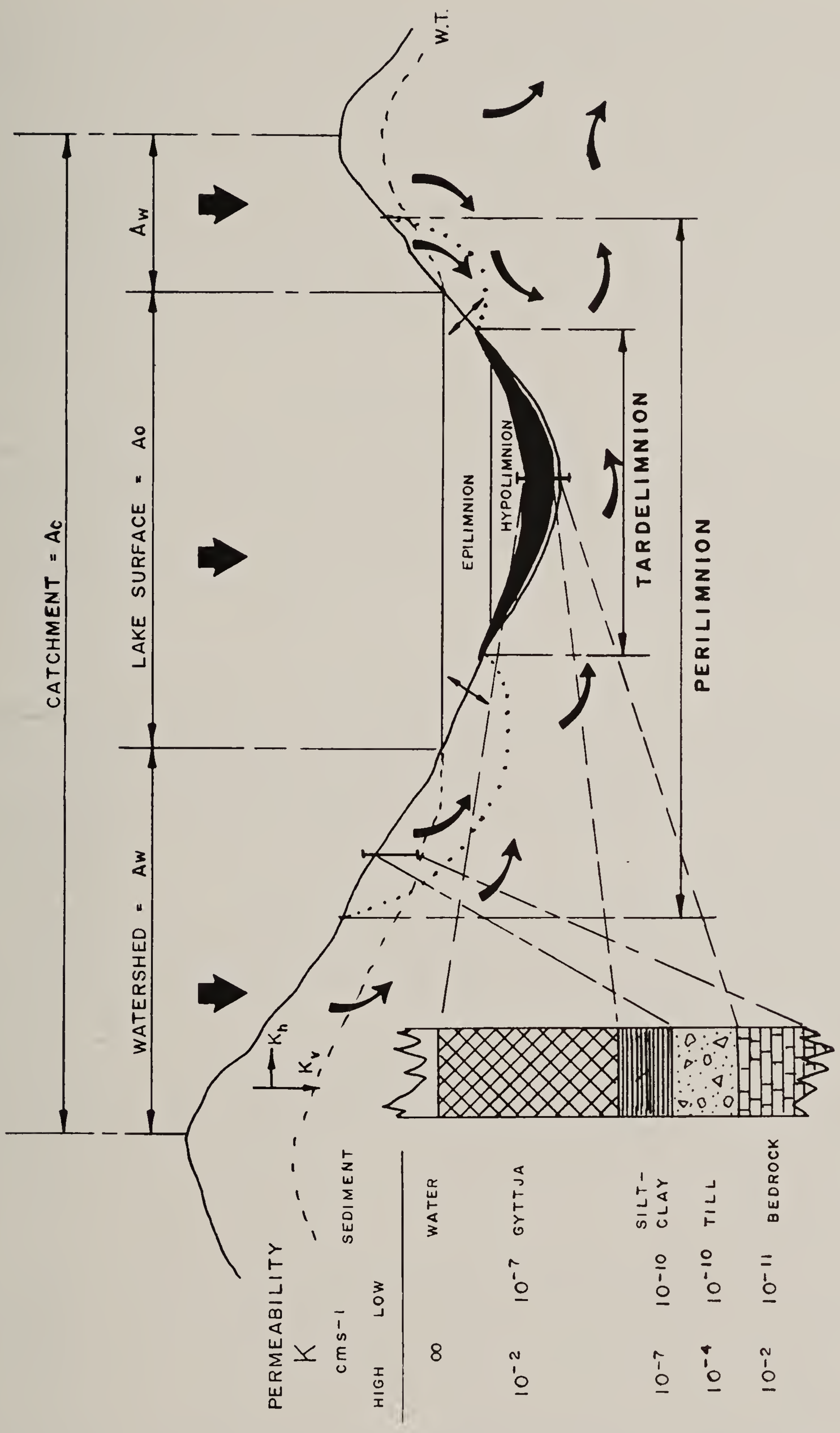

Fig. 1 Diagrammatic section through a catchment. Ground Water Table (W.T.) shown by dashes (——————), perilimnion by dots (.....). K_h = horizontal groundwater permeability coefficient; K_v = vertical groundwater permeability coefficient. Precipitation input and implied groundwater movement shown by solid arrows.

denberg (1982), and modified to represent permeabilities determined from geophysical studies by Geocon (1975), it is apparent that <20% of the Kilkenny Lake watershed is a potential ground water source to the lake.

As quantification of geochemical mass balances improves, more detailed studies are required to further refine and model the dimensions of perilimnion and tardelimnion. Seepage flux in the perilimnion may be monitored using simple and inexpensive instrumentation as described by Lee (1977). One hopes that simulation studies, as detailed in Winter (1976) will provide guidelines to determine boundaries of the perilimnion upslope from the waters edge. The tardelimnion is readily definable by physical limnological methods, using sediment probes to determine the boundary of the fine-grained gyttja and clay/silt/till aquitards.

Acknowledgements

The ideas offered here were initially presented at a Symposium, "Topics in Historical Ecology," in honour of E. S. Deevey, Jr. on the occasion of his 70th birthday at the Florida State Museum, Gainesville, Florida, 7 Dec., 1984.

I am indebted for review, comments, and clarifications by B. Freedman, J. Kerekes, and J. K. Underwood. The responsibility for proposing additional terminology, however, rests with the author.

References

Born, S.M., Smith, S.H. and **Stephenson, D.A.** 1974. The hydrogeologic regions of glacial-terrain lakes, with management and planning applications. Univ. Wisconsin, Inland lake renewal and management demonstration project. 73 p.

Case, M.L. 1978. The relationship of heavy metals to stream ecology in the prospective lead-zinc mining area at Gay's River, N.S. Unpubl. Ph.D. thesis, Dalhousie University, Halifax, N.S.

Deevey, E.S. 1970. Mineral Cycles. *Sc. Amer.* 223: 147-158.

Forbes, S.A. 1877. The lake as a microcosm. *Bull. Peoria Sci. Assoc.* 1887: 77-87.

Geoçon (1975), 1979. Report V8392. Cape Breton Development Corp. 120 p.

Lee, D.R. 1977. A device for measuring seepage flux in lakes and estuaries. *Limnol. and Oceanog.* 22:140-147.

Likens, G.E., Bormann, F.H., Pierce, R.S., Eaton, J.S. and **Johnson, N.M.** 1977. *Biochemistry of a forested ecosystem.* Springer-Verlag, N.Y. 135 p.

Lindeman, R.L. 1942. The trophic-dynamic aspect of ecology. *Ecol.* 23: 399-418.

McBride, M.S. and **Pfannkuch, H.O.** 1975. The distribution of seepage in lake beds. *Jour. Res. U.S. Geol. Survey* 3(5):505-512.

Odum, J.T. 1957. Trophic structure and productivity of Silver Springs, Florida. *Ecol. Monog.* 27: 55-112.

Ogden, J.G. and **Gillis, E.M.** 1982. *A limnological survey of Kilkenny Lake,* Cape Breton, N.S. Report, Cape Breton Development Corp., Sydney, N.S. 120 p.

Rawson, D.S. 1939. *Some physical and chemical factors in the metabolism of lakes. in:* E.R. Moulton, ed., Problems of Lake Biology. Publ. 10, AAAS, Washington, D.C. pp. 9-26.

Vanderberg, A. 1982. A one-dimensional model of unconfined ground water flow over a sloping impermeable base. *Natl. Hydrol. Inst. (Can) Res. Paper* 17, 30 p.

van Helmont, J.B. (1748). Quoted in Gabriel, M.L. & Fogel, S. "Great Experiments in Biology" 1955, Prentice Hall Inc., Englewood Cliffs, N.J.

Vollenweider, R.A. 1968. *Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to Nitrogen and Phosphorus as factors in eutrophication.* OECD, Paris: DAS/CSI/68.27. 192 p.

Winter, T.C. 1976. Numeric simulation analysis of the interaction of lakes and groundwater. *U.S. Geol. Survey Prof. Paper* 1001, 45 p.

Yuill, S.A. and **Ogden, J.G.** 1982. *Bayer's Lake watershed hydrology and hydrogeology.* Publ. Service Comm. Halifax, N.S. 33 p.

PROCEEDINGS OF MEETINGS
1875-76
HALIFAX CHAPTER

1st. Ordinary Meeting, 7 October, 1985
Marine Pharmaceuticals: A Sunken Treasure? J.L.C. Wright, National Research Council.

2nd Ordinary Meeting, 4 November, 1985
Food Production in the Aquatic Environment: The Biotechnology of Aquaculture. H. Rosenthal, Biological Station Helgoland, Germany.

3rd Ordinary Meeting, 2 December, 1985
The Nature of Infectious Diseases of Fishes of Coastal Atlantic Canada. D.K. Cone, Saint Mary's University.

4th Ordinary Meeting, 6 January, 1986
A Bigger Role for Small Cells: Changing Ideas on the Ecology of the Open Sea. M.R. Lewis, Dalhousie University.

5th Ordinary Meeting, 3 February, 1986
The Effect of Marine Pollution on the Fisheries Resources of the Maritime Province. J. Uthe, Department of Fisheries and Oceans.

6th Ordinary Meeting, 14 March, 1986
Mathematical Modelling of Sedimentary Basins: A Possible Tool for Hydrocarbon Exploration. C. Beaumont, Dalhousie University.

7th Ordinary Meeting, 7 April, 1986
Mineral Potential of the Ocean and Seabed: The Case for Offshore Mining. C. Schafer, Geological Survey of Canada.

125th Annual General Meeting, 28 April, 1986
An Essay on Fundy. G. Daborn, Acadia University.

VALLEY CHAPTER

1st Ordinary Meeting, 20 November, 1985
Tour of Sheffield Nurseries, a new plant micropropagation facility, Upper Canard, Kings County.

2nd Ordinary Meeting, 20 March, 1986
Recent work transfer to the Campden Food Preservation Research Association in England. R. Stark, Agriculture Canada, Kentville.
(Joint Meeting with Canadian Institute of Food Science and Technology).

THE PRESIDENT'S REPORT

It is gratifying to report that the Institute is financially sound and continues to provide a forum for the dissemination of scientific information through public lectures and publication and world-wide distribution of the Proceedings.

As the random selection of topics forming the basis of lecture series in previous years were, on the whole, poorly attended, this year's format was changed to seven lectures on the common theme "An Ocean for the Taking". This approach, combined wth a greater attention to publicity, was successful in improving attendance at lectures. Consequently, the Council has decided to follow this format for 1986/87, and has selected "Resources in Nova Scotia" as the theme for the lectures. The topics and speakers involved in this year's program "An Ocean for the Taking" are summarized: Marine Pharmaceuticals: A Sunken Treasure, J.L.C. Wright; Food Production in the Aquatic Environment: The Biotechnology of Aquaculture, H. Rosenthal; The Nature of Infectious Diseases of Fishes of Coastal Atlantic Canada, D.K. Cone; A Bigger Role for Small Cells: Changing Ideas on the Ecology of the Open Sea, M.R. Lewis; Pollution and the Marine Fisheries Resource in Atlantic Canada, J.F. Uthe; Sedimentary Basin Modelling: A Tool for Hydrocarbon Exploration? C. Beaumont; Mineral Potential of the Ocean and Seabed: A Case for Offshore Mining, C. Schafer.

Banking and other financial procedures of the Institute were re-structured on the recommendation of Mr. R.K. Gwynne-Timothy, chartered accountant, in order to satisfy requirements of NSERC, from which the Institute obtains an annual operating grant. I have written to Mr. Gwynne-Timothy, on behalf of the Institute, expressing our gratitude for his services as financial consultant and for agreeing to act as auditor of the Institute's Financial Statement for the years 1984/85 and 1985/86. As these services have been provided at no cost to the Institute, I feel sure that Members present will wish to express their appreciation so that it can be recorded in the minutes of this meeting.

As Dr. Gary Hicks has tendered his resignation as Editor of the Proceedings, effective May 31, 1986, the Council recently ratified the appointment of Dr. Alan Taylor as Editor. In addition, Dr. John Walter indicated that other commitments prevent him from continuing to serve as Treasurer.

It is the opinion of the existing Council that the Institute could become more effective if more emphasis was placed on publicity, membership, and the choice of topics selected for public lectures. A member of Council should be given the responsibility for ensuring that the activities of the Institute are reported adequately in the press, radio and television. Furthermore a Membership Registrar should be appointed to keep a register of members, solicit new memberships, collect dues on behalf of the Treasurer, issue receipts and, in general, provide the Treasurer with the statistical information required for the NSERC grant application. Public lectures would also be improved by Council selecting a theme for the following year's annual lecture series and appointing a member, or small committee, to select a slate of speakers and organize and publicize the lectures, in collaboration with the member responsible for publicity. Apart from improved efficiency, this reallocation of duties will reduce the workload on the President and Treasurer, and thus permit them to devote more time to their other functions.

It has been an honour and privilege to serve the Institute as President, and I would like to take this opportunity to thank the members of the Executive and Council for their interest, hard work and support during my tenure of office. However, I think the Institute owes a special vote of thanks to Gary Hicks and John Walter for their dedicated service as Editor of the Proceedings and as Treasurer.

A. Gavin McInnes

RECOMMENDATIONS AUX AUTEURS

La Revue *Proceedings of the Nova Scotian Institute of Science* publie les travaux de l'Institut, des articles originaux et des notes avant trait aux sciences naturelles aux Provinces atlantiques, surtout dans les domaines de la biologie et de la géologie. Les manuscrits peuvent être en anglais ou en français, et seront soumis à l'avis d'experts avant d'être acceptés.

Les texts doivent être dactylographiés à interligne double, sur des feuilles de papier blanc 21.5 cm sur 28 cm (8.5 po sur 11 po), avec marges de 4 cm (1.5 po). Ne souligner que les passages destinés à être imprimés en italique; utiliser les majuscules dans le seul cas où les lettres ou les mots en question doivent paraître en majuscules à l'impression. La mise en page et la typographie suivront le modèle du présent ouvrage. Le texte original doit être accompagné d'une copie. Chaque page doit être numéroté, la première page ne portant que le titre, le nom des auteures, la mention de l'université ou autre éstablissement auquel ils sont affectés, et des notes infrapaginales éventuelles.

L'orthographe doit se conformer au **Larousse encyclopédique.** Les auteurs sont responsables de l'uniformité de l'orthographe dans leurs texts.

Les abréviations, la nomenclature et les symboles des unités de mesure doivent se conformer aux normes internationales. Les unités métriques (SI) et les décimales doivent être utilisées dans la mesure du possible. Pour les dates, adopter l'order jour/mois/année. Ne pas faire suivre d'un point les abbréviations "mm, kg, ME, CNRC", etc.

Les tableaux taxonomiques doivent se présenter, dans des cas de la zoologie et de la paléontologie, sous forme de descriptions dichotomiques alignées verticalement, et pour la botanique sous forme multilinéaire étagée. La synonymie, en botanique, en zoologie et en paléontologie, doit être presentée succinctement: taxon, auteur, année: page, avec citation au complet aux indications bibliographiques.

Un résumé dépassant pas 200 mots doit précéder le corps du texte. Le texte lui-même doit comprendre les sections suivantes: introduction, méthodes, résultats ou observations, discussion, références bibliographiques. Dans certains cas, une synthèse de deux ou de plusieurs de ces sections peut être souhaitable.

Les références bibliographiques doivent être vérifiées auprés des publications d'origine, et doivent être identifiées dans le texte par les mentions auteur et date, entre parenthèses. Les références bibliographiques doivent être arrangées par ordre alphabétique en fin de texte. Les références aux articles parus dans des revues doivent comporter les éléments suivants: nom du journal, numéro du volume, pagination complète. L'abréviation des titres revues doivent se conformer au **Bibliographic Guide for Editors and Authors** (American Chemical Company, 1974). Pour les revues qui n'y figurent pas, consultera la **World List of Scientific Periodicals** (Butterworths, 1963). Nous donnons ci-dessous quelques examples de référence aux revues, livres et recueils:

Auteur, U.N. et Autre, T.E.L. 1978. Titre de l'articles. *Nom de la revue,* (volume) 99, 1-10, (omettre le mot "volume").

Auteur, U.N. et Coauteur, S.O.N. 1978. *Titre du livre au complet.* Editeur, Ville.

Auteur, U.N. 1978. Titre de l'article. In *Titre du livre ou de Recueil.* (réd. A. Lenoir et B. Leblanc). Editeur, Ville, pp. 256-301.

Les tableaux doivent être numérotés en chiffres romains, avoir un titre concis et être signalés dans le texte. Ils ne doivent pas comporter de lignes verticales. Les tableaux doivent être soumis sur feuilles à part.

Les dimensions de originaux des illustrations ne doivent pas dépasser le triple de celles de leur reproduction définitive, soil 11 cm sur 10 cm. Les figures, y compris celles des planches, seront numérotées en chiffres arabes, et doivent être signalées dans le texte. Les dessins originaux doivent être exécutés à l'encre de Chine sur du papier blanc. Tous les traits doivent être suffisamment épais pour en assurer la reproduction bien nette. Les lettres et autres caractères doivent être de dimensions à rester parfaitement lisibles à la réduction, et en aucun cas ne doivent être inférieurs en à l'état réduit, a 1 mm, hauteur. Les origineaux des illustrations son exigés, ainsi qu'un jeu de copies bien propres. Les légendes des illustrations doivent être écrite à la machine sur feuille à part.

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